U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-257 911

Environmental Assessment Perspectives

GCA Corp, Bedford, Mass GCA Technology Div

Prepared for

Industrial Environmental Research Lab, Research Triangle Park, N C

Mar 76

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-76-069	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Environmental Assessment Perspectives		5. REPORT DATE March 1976
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) P. F. Fennelly, D. F. Durocher, A. S. Werner, M. T. Mills, S. M. Weinstein, A. H. Castaline, and C. Young		8. PERFORMING ORGANIZATION REPORT NO. GCA-TR-75-21-G(2)
9. PERFORMING ORGANIZATION NAME AND ADDRESS GCA Corporation GCA/Technology Division Bedford, Massachusetts 01730		10. PROGRAM ELEMENT NO. EHB525; ROAP AAU-004
		11. CONTRACT/GRANT NO. 68-02-1316, Task 13
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Industrial Environmental Research Laboratory Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Task Final; 3/75-1/76
		14. SPONSORING AGENCY CODE EPA-ORD

15. SUPPLEMENTARY NOTES Project officer for this report is Ronald A. Venezia, Mail Drop 62, Ext 2547.

16. ABSTRACT

The report: (1) defines environmental assessment (EA) programs and their role in energy system development; (2) indicates data requirements of an EA; (3) outlines exemplary methodologies for acquiring the necessary data; (4) serves as a technology transfer vehicle by providing background information on environmental monitoring and modeling, which can be used in EAs; (5) summarizes the extent, quality, applications, and location of existing information resources which can be used in the planning of EAs; and (6) summarizes existing or proposed standards and criteria for evaluating air, water, and land based pollution. The report includes: waste stream characterization and pollution identification, indirect pollution associated with energy system development, estimating the sphere of influence of an energy system, evaluation of environmental impact, methodology for conducting source tests, use of dispersion models, available data banks and information sources, and existing and proposed environmental regulations. Each topic is explored to the degree necessary to acquaint the user with current standards, sampling and analytical techniques, and environmental models. General discussions are supplemented where possible with specific examples in order to clarify some of the concepts presented.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Information Centers	Environmental Assessment	13B	05B
Assessments	Criteria		14B	
Power Sources	Regulations	Technology Transfer	10B	
Data Acquisition	Properties	Energy Systems		
Monitors	Tests			
Mathematical Models			12A	
	Dispersions			

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 248
	20. SECURITY CLASS (This page) Unclassified	22. PRICE 8.00

EPA Form 2220-1 (9-73)

PRICES SUBJECT TO CHANGE

EPA-600/2-76-069
March 1976

ENVIRONMENTAL ASSESSMENT
PERSPECTIVES

by

P.F. Fennelly, D.F. Durocher, A.S. Werner, M.T. Mills,
S.M. Weinstein, A.H. Castaline, and C. Young

GCA Corporation
GCA/Technology Division
Bedford, Massachusetts 01730

Contract No. 68-02-1316, Task 13
ROAP No. AAU-004
Program Element No. EHB-525

EPA Task Officer: Ronald A. Venezia

Industrial Environmental Research Laboratory
Office of Energy, Minerals, and Industry
Research Triangle Park, NC 27711

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Washington, DC 20460

ABSTRACT

The report: (1) defines environmental assessment (EA) programs and their role in energy system development; (2) indicates data requirements of an EA; (3) outlines exemplary methodologies for acquiring the necessary data; (4) serves as a technology transfer vehicle by providing background information on environmental monitoring and modeling, which can be used in EAs; (5) summarizes the extent, quality, applications, and location of existing information resources which can be used in the planning of EAs; and (6) summarizes existing or proposed standards and criteria for evaluating air, water, and land based pollution. The report includes: waste stream characterization and pollution identification, indirect pollution associated with energy system development, estimating the sphere of influence of an energy system, evaluation of environmental impact, methodology for conducting source tests, use of dispersion models, available data banks and information sources, and existing and proposed environmental regulations. Each topic is explored to the degree necessary to acquaint the user with current standards, sampling and analytical techniques, and environmental models. General discussions are supplemented where possible with specific examples in order to clarify some of the concepts presented.

CONTENTS

Page

Abstract iii

List of Figures xi

List of Tables xiii

Acknowledgments xv

Sections

I Introduction 1

Purpose of the Document 1

Potential Uses of Environmental Assessment Reports 2

Organization of the Document 2

Limitations of the Document 3

References 5

II Integration of Environmental Assessment Activities with Energy System Development 7

Framework for Energy System Development 7

Definition of an Environmental Assessment Program 9

Difference Between "Environmental Assessment" and "Environmental Impact Statement" 11

Importance of Feedback Loops 12

The Levels of Effort Required for an Environmental Assessment 12

CONTENTS (continued)

Sections Page

Goals Within an Environmental Assessment Program 15

Outline of a Sample Environmental Assessment 15

Environmental Assessment Reports 18

References 19

III Process Characterization and Waste Stream Analysis 21

Introduction 21

Methodology for Process Evaluation 22

Unit Operations Analysis 26

A Sample Unit Operations Scheme 27

Determination of Emission Rates 30

Inventory of Reactants and Products 30

Identify Conceivable Pollutants 32

Determination of Emission Rates 35

Other Process Characteristics of Interest 39

References 40

IV Estimate Pollution from Associated Development 43

Introduction 43

Methodology for Projecting Induced Growth 44

General Approach 44

Elements of Assessment Process 45

Constraints Upon Assessment 48

Discussion of Individual Assessment Elements 49

CONTENTS (continued)

Sections Page

Methodology for Evaluating Environmental Effects 55

General Approach 55

Air Quality Impacts 58

Water Quality Impacts 60

Land Impacts 62

Noise Impacts 63

Other 64

References 65

V Estimating the Sphere of Environmental Influence 67

Introduction 67

Methodology for Estimating the Sphere of Influence 68

Process Emission Characteristics 68

Survey of Pathways for Pollutant Transport 72

Survey of Site-Related Data 74

Modeling Techniques 80

References 84

VI Assessing the Environmental Impacts of Energy Systems 87

Introduction 87

Methodology for Evaluating Environmental Impacts 88

Phase I Evaluation 90

Phase II Evaluation 90

Analysis of Measures for Control or Reduction 92

CONTENTS (continued)

Sections — Page

Evaluation Criteria 93
  Laws 94
  Scientific Judgments 95
  Social Criteria 98
Impact Identification 99
Examples of Possible Decisions 100
Assessing the Environmental Impact of Systems at Different Stages of Development 102
  Bench Scale or Conceptual Models 102
  Pilot Plant 103
  Demonstration Plant 103
References 104

Appendices

A Source and Ambient Testing as Part of an Environmental Assessment Program 107
  Introduction 107
  Source Tests: Sampling and Analysis 108
    Presampling Survey 108
    Sampling 109
    Analytical Techniques 121
  Ambient Tests 124
    Introduction 124
    Ambient Monitor Siting 127

CONTENTS (continued)

Appendices | Page

Sampling and Analysis with Respect to Ambient Testing Programs 129

Identifying Source Background Contaminants 134

Development of Quality Control Program 136

Introduction 136

Major Features of a Quality Control Program 136

Decisions Based on Quality Control Tests 139

Reporting Error 141

Cost of Reducing Errors 141

References 142

B Dispersion Models 147

Introduction 147

Atmospheric Transport Models 147

Basic Concepts and Formulations 148

Description of Atmospheric Transport Models of Interest 154

Pollutant Transport Models for Water 160

Modeling Pollutant Transport in Soils 162

Models for Heat Transport 165

Unified Approach to Transport Modeling 168

Example Model Application 169

References 174

CONTENTS (continued)

Appendices | Page

C Data Retrieval and Information Systems Applicable to Environmental Assessments 179

- Introduction 179
- References 181

D Pollution Legislation and Future Perspectives 205

- Introduction 205
- Existing Standards 212
  - Air 212
  - Water 212
  - Solid Waste 216
- Pending Standards 216
  - Air 216
  - Water 216
- The Future 221
  - Air 221
  - Water 221
- References 221

E Bibliography 223

- Section II. Integration of Environmental Assessment Activities with Energy System Development 223
- Section III. Process Characterization and Waste Stream Analysis 224

CONTENTS (continued)

Appendices | Page

Section IV. Estimate Pollution From Associated Development 224

General Environmental Issues and Analyses 224

Environmental Quality Guidelines 225

Land Resources and Environmental Impacts 225

Water Resources and Environmental Impacts 225

Air Impacts 226

Noise Impacts 227

Other Environmental Impacts 227

Section V. Estimating the Sphere of Environmental Influence 228

Section VI. Assessing the Environmental Impacts of Energy Systems 228

Appendix A. Source and Ambient Testing as Part of an Environmental Assessment Program 230

Air 230

Water 234

Miscellaneous 236

Appendix B. Dispersion Models 236

Appendix C. Data Retrieval and Information Systems Applicable to Environmental Assessments 237

Appendix D. Pollutant Legislation and Future Perspectives 238

FIGURES

No.		Page
1	Interrelationships Between Various Sections of the Document	4
2	Flow Chart for Energy System Development	8
3	Flow Diagram for a Comprehensive Environmental Assessment Program	10
4	Methodology for Process Evaluation	23
5	Simplified Scheme for Unit Operations of an Energy System	28
6	Schematic Diagram of an Atmospheric Pressure Fluidized Bed Combustion System	29
7	Classification for Hazardous Materials Generated in the Extraction and Processing of Coal and Oil	34
8	Ranking Scheme of the Hazardous Classes of Pollutants in Effluent Streams in a Petroleum Refinery	36
9	Diagram Summarizing the Types of Basic Stream Data to be Collected for Environmental Assessments	37
10	Methodology for Projections of Induced Growth and Development	46
11	Methodology for Growth Allocation and Impact Evaluation	47
12	Methodology for Assessing Environmental Effects as a Result of Induced Growth	56
13	Methodology for Predicting the Sphere of Influence	69
14	Pollutant Emissions and Transport Pathways	73

FIGURES (continued)

No.		Page
15	Material Balance Within a Three-Component Compartmental Model	82
16	Flow Diagram for Decisions Based on Environmental Assessments	89
17	Diagram Summarizing the Types of Basic Stream Data to be Collected for Environmental Assessments	125
18	Illustrative Chemical Analysis Strategy for Environmental Assessments	126
19	Illustration of Pollutant Roses for SO_2	135
20	Quality Assurance Elements and Responsibilities	137
21	Vertical Dispersion Coefficient as a Function of Downwind Distance from the Source	149
22	Series of Trajectories Generated by the ARL Model	159
23	Pollutant Material Balance for Water and Sediment Phases of a Stream	161
24	Computer Simulation of Mercury Transport During a Stream Tagging Experiment; Data Taken at 10, 20, 40, 70, and 100 Meters Downstream from Injection Point	163
25	The Cation Concentration Profiles X(z,t) and Y(z,t) in Liquid and Solid Phases	166
26	Calculated 14-Year Fly Ash Deposition Pattern in the Vicinity of a Coal-Fired Power Plant	172

TABLES

No. Page

1 Matrix Relating Various Assessment Tasks to Stages of System Development 14

2 Partial List of Material Flows from an Atmospheric Pressure Fluidized Bed Combustion System 31

3 Principal Environmental Assessment Analysis Factors to be Considered in the Impact Evaluation of a Pollutant Source 91

4 Examples of Process-Related Decisions Which May be Encountered in an Environmental Assessment 100

5 Examples of Site-Related Decisions Which May be Encountered in an Environmental Assessment 101

6 A Selection from EPA's Recommended Procedures for Sampling and Preservation of Water Samples 115

7 Preservatives for Water Samples 117

8 Primary and Secondary Leachate Parameters to be Measured 121

9 Criteria for Selection of Analytical Methods 122

10 Background Concentrations for Air Pollutants 131

11 Observed Mean Positive Trace Metal Values by Basin 133

12 Calculated Concentration Ratios in Soil Corresponding to 0.01 g/cm^2 Total Fly Ash Fallout 173

13 Data Handling and Information Systems at the Federal Level 183

TABLES (continued)

No.		Page
14	Federal Data Retrieval and Information Systems - Air	185
15	Federal Data Retrieval and Information Systems - Water	189
16	Federal Data Retrieval and Information Systems - Solid Waste	194
17	Federal Data Retrieval and Information Systems - Noise	195
18	Federal Data Retrieval and Information Systems - Toxicological Substances	196
19	Federal Data Retrieval Systems - Total Environment	199
20	Federal Legislation Concerning Environmental Assessment Activities	207
21	Ambient Air Standards	213
22	Summary of Hazardous Air Pollutant Standards	214
23	Summary of Air Emission Standards for New or Substantially Modified Sources	215
24	Wastewater Effluent Guidelines and Standards - Steam Electric Generating Point Source Category	217
25	Summary of Federal Guidelines and State Regulations for Solid Waste Disposal Practices	218
26	Sources for Which Standards Have Been Proposed and Review Initiated	219
27	National Interim Primary Drinking Water Standards	220

ACKNOWLEDGMENTS

The authors would like to acknowledge helpful discussions with: Dr. Ronald Venezia, Dr. Dale Denny, Mr. Robert Hangebrauck, Dr. Gene Tucker, Dr. Max Samfield, Mr. Joe McSorley, Mr. James Dorsey, Mr. Robert M. Statnick, Mr. L. D. Johnson, Mr. D. Bruce Henschel, Environmental Protection Agency (EPA), Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina; Mr. D. J. von Lehmden, Environmental Monitoring and Support Laboratory, Research Triangle Park, North Carolina; Mr. Clyde Dial, Mr. Guy Nelson, Mr. Victor Jelen, EPA, National Environmental Research Center, Cincinnati, Ohio; Mr. Don Gilmore, EPA, Environmental Monitoring and Support Laboratories, Las Vegas, Nevada; Mr. D. J. Canon, Mr. B. A. Tichenor, EPA, Environmental Research Laboratory, Corvallis, Oregon. Members of the GCA/Technology Division Staff who provided assistance were: Mr. Mark I. Bornstein, Mr. James W. Carroll, Mr. Reed Cass, Dr. Douglas W. Cooper, Mr. Gordon Deane, Ms. Becky Sue Epstein, Mr. Lawrence Gordon, Mr. David Lynn, Mr. Manuel Rei, Ms. Josephine Silvestro, Mr. Richard Wang, Mr. Norman F. Surprenant, and Dr. Leonard M. Seale.

The authors would also like to express their appreciation to Mr. Morris M. Penny, Dr. Sidney V. Bourgeois, Dr. John H. McDermit, Dr. D. Richard Sears, and Dr. Michael G. Klett of the Huntsville Research and Engineering Center, Lockheed Missile and Space Company, Huntsville, Alabama; and Mr. R. W. Barnes, Dow Chemical U.S.A., Midland, Michigan, and Mr. P. E. Muhlberg and Mr. B. P. Shepherd, Dow Chemical U.S.A., Freeport, Texas, for their critiques of an earlier draft of this document. Many of their suggestions have been incorporated in the final version.

SECTION I

INTRODUCTION

PURPOSE OF THE DOCUMENT

Over the last several years, increased environmental consciousness and economic and raw material constraints have forced a more systematic approach to energy system development. As the need for critical choices between various technologies becomes imminent, the value of systematic evaluation is increasing. To provide information on the environmental aspects of these systems, activities known as "environmental assessments" are evolving. The purpose of this document is to define the environmental assessment process in relation to energy system development.

To meet this objective, this document is designed to:

- Define environmental assessment programs and their role in energy system development
- Indicate the data requirements of an environmental assessment
- Outline exemplary methodologies for acquiring the necessary data
- Serve as a technology transfer vehicle by providing background information on both conventional and state-of-the-art techniques in environmental monitoring and modeling which can be used in environmental assessments
- Summarize the extent, quality, applicability, and location of existing information resources
- Summarize existing or proposed standards and criteria for evaluating air, water, and land based pollution.

Because the initiation of technology transfer between a wide variety of disciplines is one of the primary purposes of this document, the technical discussion is very general. Wherever possible, references are made to more detailed articles, reviews, or annotated bibliographies. The aim is to assist specialists in certain areas to become familiar with the technical problems and the information resources in related disciplines.

POTENTIAL USES OF ENVIRONMENTAL ASSESSMENT REPORTS

The importance of rapid and efficient technology transfer to proper energy and environmental policy decisions cannot be overestimated. Listed below are some of the areas in which environmental assessment data will be of significant benefit:

- Identification of potential environmental impact of energy systems
- Energy system design
- Development of source performance standards for specific pollutants
- Development of improved control technology
- Development of improved environmental monitoring technology
- Design of toxicological studies
- Design of ecological field tests
- Discovery of "unanticipated" pollutants
- Natural resource management
- Land use planning.

ORGANIZATION OF THE DOCUMENT

This document consists of five major sections and four appendices. Each section addresses a basic task of an environmental assessment program, and each appendix provides background information for the various tasks. The interrelationships between the various sections and appendices are shown in Figure 1. In some situations, it may not be feasible or necessary to execute some of the assessment tasks; accordingly, each section can be used independently. To gain the proper perspective on environmental assessment programs, however, one should become familiar with the content of all the sections and appendices.

LIMITATIONS OF THE DOCUMENT

This document is aimed primarily at defining the scope of an environmental assessment program; it is not intended to provide a unique or preferred way to conduct such a program. Environmental assessments are discussed primarily in the context of the interaction between an energy or fuel-generating system and its adjacent surroundings. Potential environmental impacts from the use of the products or by-products of a system have not been included. For example, if one is dealing with a coal-liquefaction plant, the discussion here is applicable primarily in describing methods by which an assessment can be made of the manner in which the plant itself may interact with its surroundings. The discussion does not deal to any significant extent with the manner in which the utilization of the coal-liquefaction products in other industries may affect the environment. Such an assessment of the potential environmental consequences of using various products or by-products may require its own distinct methodology. Furthermore, this document is not designed for the preparation of environmental impact statements, although it may be helpful in this regard.*

Economic and sociological factors have not been considered to any significant extent; time restrictions prevented extensive coverage. It is

---

*The Council on Environmental Quality has recently released a comprehensive report entitled "Energy Alternatives - A Comparative Analysis" which is aimed specifically at assisting in the preparation of environmental impact statements for energy systems (U.S. Government Printing Office Stock Number 041-001-00025-4).

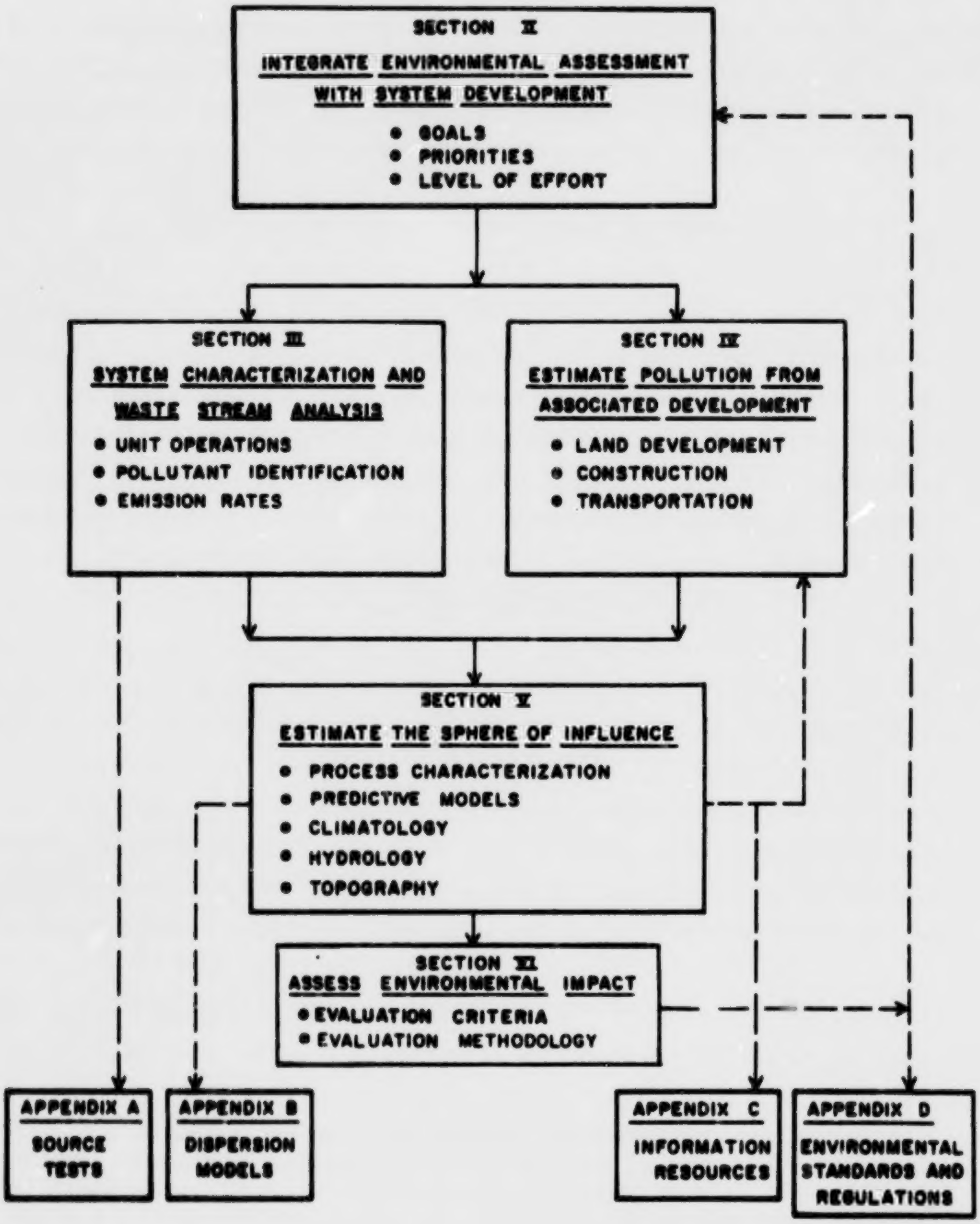


Figure 1. Interrelationships between various sections of the document

recognized that these factors may often be crucial to the success or failure of new energy systems. Their omission is not meant to underemphasize their importance. Problems in these areas are sufficiently complex to warrant separate treatment.

In general, problems which are unique to nuclear systems have not been covered. These are discussed in detail in guidelines from nuclear regulatory agencies.[1,2]

REFERENCES

1. Atomic Energy Commission. Environmental Survey of the Uranium Cycle. U.S. Government Printing Office, Washington, D.C. 1974.

2. Council of Environmental Quality. The Nuclear Energy-Fission Resource System, Chapter 6. In: Energy Alternatives - A Comparative Analysis. U.S. Government Printing Office, Washington, D.C. 1975.

SECTION II

INTEGRATION OF ENVIRONMENTAL ASSESSMENT ACTIVITIES WITH ENERGY SYSTEM DEVELOPMENT

FRAMEWORK FOR ENERGY SYSTEM DEVELOPMENT

Energy system development generally proceeds along the pathways shown in Figure 2. The first step in system development is to define the appropriate energy needs, and one deals here with three basic sectors: electric power generation, specific industrial/commercial needs, or individual residential requirements. Energy needs can be defined on a national, regional, state, or local basis, depending on the task at hand.

Once the requirements are determined, the possible technological options can be investigated. Options can range from available and proven systems (e.g., coal-fired boilers) to those still at the conceptual stage of development (i.e., little or no hardware available — e.g., use of ocean thermal gradients).

Both environmental and economic assessments should be conducted to determine the relative advantages and disadvantages of each option. Based on these evaluations, an optimum system is chosen. To satisfy existing legal requirements, an environmental impact statement must be prepared for the chosen system. Construction begins when the impact statement is accepted by the appropriate federal, state, or local regulatory agencies. Once the system is operational, field tests can be performed to insure the environmental impact is within the predicted bounds.

Preceding page blank

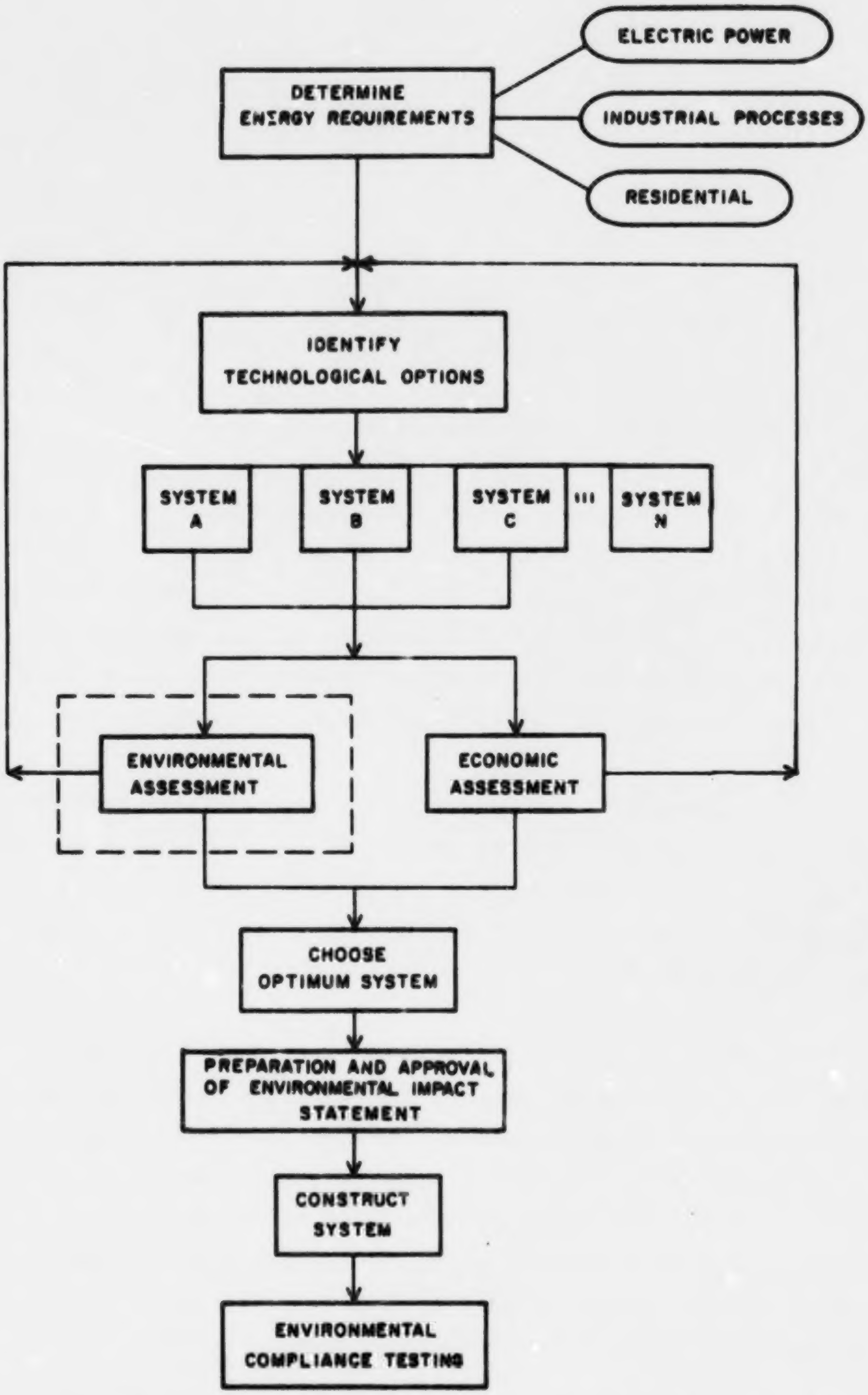


Figure 2. Flow chart for energy system development

This document is concerned primarily with the environmental assessment step in Figure 2 and its role in energy system development. A number of reports and papers discussing some of the other areas in Figure 2 are listed in the Bibliography in Appendix E.

DEFINITION OF AN ENVIRONMENTAL ASSESSMENT PROGRAM

An environmental assessment may be defined as follows:*

> An environmental assessment of an energy system (or an industrial process) consists of a comprehensive physical, chemical and bioassay characterization of its waste streams, and calculations of estimated incremental loadings to ambient air, water and land. The assessment further includes an analysis of the impact of the incremental loadings on human health and ecological systems— insofar as such knowledge can be readily quantified with present knowledge of health and ecological effects (i.e., without specific studies to determine such effects). The goal of an environmental assessment is to determine whether a system is environmentally acceptable. If there is insufficient information available to make this determination, the identification and the acquisition of the data which are needed to make such a determination become primary goals. This information is essential for establishing research and development priorities in areas such as waste control technology or ecological studies. In cases where comparative assessments are being made of two or more processes, an additional goal may be to determine which one(s) are environmentally preferable.

An environmental assessment is aimed at uncovering potential pollution problems as early in the development cycle as possible. The advantage is obvious — the sooner a possible problem is discovered, the more time available for its evaluation and solution.

Figure 3 provides a schematic representation of a comprehensive environmental assessment program. Because the level of effort will often depend

---

*Based on definition in Environmental Assessment Guideline Document, Draft, May 1975, prepared by W. G. Tucker et al., Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

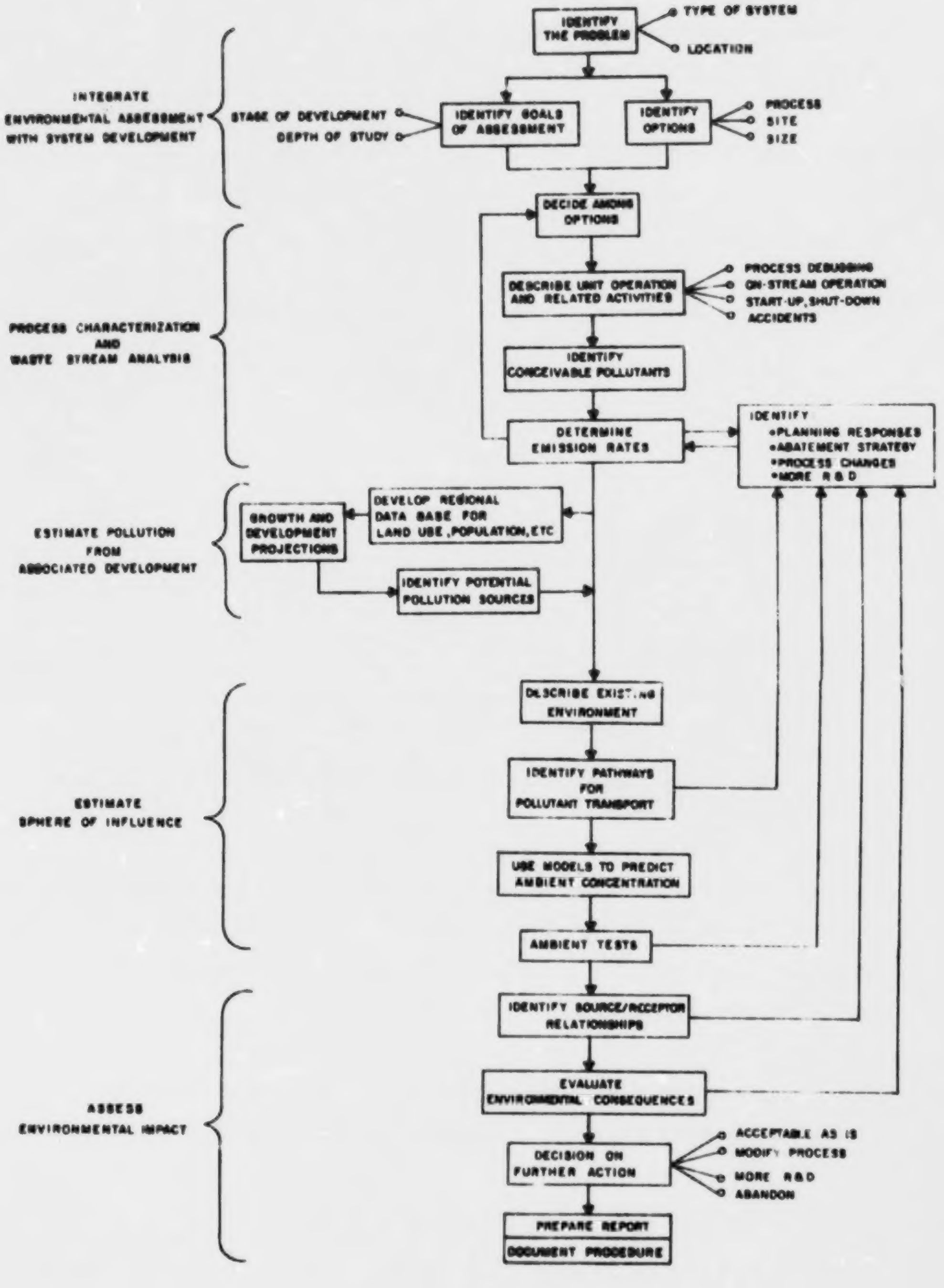

IDENTIFY THE PROBLEM
TYPE OF SYSTEM
LOCATION
INTEGRATE ENVIRONMENTAL ASSESSMENT WITH SYSTEM DEVELOPMENT
STAGE OF DEVELOPMENT
DEPTH OF STUDY
IDENTIFY GOALS OF ASSESSMENT
IDENTIFY OPTIONS
PROCESS
SITE
SIZE
DECIDE AMONG OPTIONS
PROCESS CHARACTERIZATION AND WASTE STREAM ANALYSIS
DESCRIBE UNIT OPERATION AND RELATED ACTIVITIES
PROCESS DEBUGGING
ON-STREAM OPERATION
START-UP, SHUT-DOWN
ACCIDENTS
IDENTIFY CONCEIVABLE POLLUTANTS
DETERMINE EMISSION RATES
IDENTIFY
•PLANNING RESPONSES
•ABATEMENT STRATEGY
•PROCESS CHANGES
•MORE R & D
ESTIMATE POLLUTION FROM ASSOCIATED DEVELOPMENT
GROWTH AND DEVELOPMENT PROJECTIONS
DEVELOP REGIONAL DATA BASE FOR LAND USE, POPULATION, ETC
IDENTIFY POTENTIAL POLLUTION SOURCES
DESCRIBE EXISTING ENVIRONMENT
ESTIMATE SPHERE OF INFLUENCE
IDENTIFY PATHWAYS FOR POLLUTANT TRANSPORT
USE MODELS TO PREDICT AMBIENT CONCENTRATION
AMBIENT TESTS
ASSESS ENVIRONMENTAL IMPACT
IDENTIFY SOURCE/RECEPTOR RELATIONSHIPS
EVALUATE ENVIRONMENTAL CONSEQUENCES
DECISION ON FURTHER ACTION
ACCEPTABLE AS IS
MODIFY PROCESS
MORE R & D
ABANDON
PREPARE REPORT
DOCUMENT PROCEDURE

Figure 3. Flow diagram for a comprehensive environmental assessment program

on the development status of the energy system, the performance of tasks in Figure 3 can be tailored to suit individual needs. For example, sophisticated pollutant dispersion estimates are probably unwarranted for experiments conducted in a small pilot plant. (Guidance as to which activities are most appropriate at the various development stages of an energy system is discussed later in this section.)

Difference Between "Environmental Assessment" and "Environmental Impact Statement"

The terms "Environmental Impact Statement" and "Environmental Assessment" are related but they are not synonomous, and it is important to emphasize the differences between them. An "Environmental Impact Statement," in general, is prepared to obtain approval from a regulatory agency in order to build a specific structure or technological system. In essence, it is a legal document. The impact statement is usually formulated to argue the case as to whether or not a specific facility can be constructed and operated in an environmentally acceptable manner at some preselected site.* The Council of Environmental Quality (CEQ) has presented detailed discussions on the role of Environmental Impact Statements[1] and has also presented guidelines for their preparation.[2]

An "Environmental Assessment" is concerned with the general question: is a proposed system (i.e., its effluent streams and any related construction and development activities) sufficiently well characterized that one can confidently predict its environmental impact? Contrary to an impact statement, which is usually aimed at fulfilling statutory regulations, an "environmental assessment" is more of a design or planning tool. Its aim is to highlight technical areas needing additional research and to provide adequate lead time for developing related technology (e.g., pollution control equipment). It is not necessarily limited to already existing systems; an environmental assessment can be performed on systems still at the conceptual stage of development (i.e., those in which technical feasibility is being theoretically explored without any hardware necessarily available). It is not restricted to specific geographic location; in fact, an environmental assessment could have as one of its goals site selection.

---

*There are exceptions; for instance, many federal agencies are now required to prepare impact statements which establish the manner in which their regulatory policies will affect the environment.

Importance of Feedback Loops

Because of the multidisciplinary nature of environmental assessment programs, effective feedback loops are essential. Their major purpose is to ensure that data are transferred rapidly and efficiently between experts in the various scientific and engineering disciplines involved in the energy system design and analysis. Figure 3 highlights areas where feedback is important.

THE LEVELS OF EFFORT REQUIRED FOR AN ENVIRONMENTAL ASSESSMENT

Basically, the assessment parallels the physical processes associated with any pollutant source: emitted pollutants are identified and quantified (if possible); the transport (and conversion) of the pollutants is investigated to indicate the sphere of influence; and the projected sphere of influence is examined to determine the potential impact.

The major tasks in an environmental assessment are summarized below:

- Integrate Environmental Assessment with System Development - The first step is to define the scope of the environmental assessment, and this obviously depends on the stage to which the system has developed. The technical literature must be reviewed to determine the state-of-the-art understanding of the system. Various options in which the system may be used should be identified. Goals for the assessment program should be established.

- Process Characterization and Waste Stream Analysis - All potential pollutants from the process should be identified. On the basis of source tests, available pilot plant data, materials and energy balances, or theoretical calculations, the effluent streams from an operation should be characterized to indicate where and in what quantities potentially hazardous compounds could be discharged.

- Estimate Pollution From Associated Development - In many cases, the pollution from the actual construction of an energy facility or the land development associated with its existence can cause substantial environmental problems — sometimes more severe than those produced from the effluent streams of the energy facility. These indirect pollution effects need to be evaluated.
- Estimate the Sphere of Influence - Either real or hypothetical sites can be used to estimate the sphere of influence of the energy system. Each site should be characterized as to its topography, hydrology, and climatology. Federal and state data banks can be consulted to determine the prevailing ambient concentrations of pollutants of interest. Based on this information, scaled emission rates can be combined with dispersion models to predict changes in ambient concentrations.
- Assess Environmental Impact - Within the estimated sphere of influence for each proposed site, the potential pollutant impact should be established using state-of-the-art information on both biological and materials effects of pollutants.

The level of effort expended on each of the tasks will vary with the stage of development of the energy system. For example, in studying a system still at the pilot plant stage, process characterization and waste stream analysis would probably be the predominant task. Estimating pollution from associated development and estimating the overall sphere of influence might be conducted only to the extent of identifying potential problems as opposed to providing quantitative estimates of the problems.

The correspondence between assessment tasks and the various stages of energy system development are summarized in Table 1.

Table 1. MATRIX RELATING VARIOUS ASSESSMENT TASKS TO STAGES OF SYSTEM DEVELOPMENT

Assessment tasks / Stage of development	Integrate assessment with system development			Process characterization – waste stream analysis			Estimate pollution from associated development			Estimate sphere of influence				Assess environmental impacts	
	Identify goals	Identify options	Decide among options	Unit operations and related activities	Identify conceivable pollutants	Determine emission rates	Develop regional data base	Growth projections	Identify pollution sources	Describe existing environment	Identify pathways for pollutant transport	Use models to predict ambient concentrations	Ambient tests	Identify source/receptor relationships	Evaluate environmental consequences
Conceptual stage	○	○	▲	○	○	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Laboratory bench apparatus	○	○	▲	○	○	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Pilot plant	○	○	○	○	○	○	▲	▲	▲	▲	○	○	▲	○	○
Demonstration plant	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Full scale commercial plant	○	▲	▲	○	○	○	○	○	○	○	○	○	○	○	○

NOTE: ○ - indicates task which usually applies.
▲ - indicates task which may only apply in some cases.

GOALS WITHIN AN ENVIRONMENTAL ASSESSMENT PROGRAM

An environmental assessment is primarily a planning tool. Its purpose, in many respects, is to uncover unexpected problems at the earliest possible time within the development program. In many cases, environmental assessments will be conducted on energy systems for which commerical application is still many years away; therefore, the assessment will provide maximum benefit if the goals or objectives within the program are established with a futuristic perspective. In many cases, this may involve making assumptions about future environmental regulations or source performance standards. The better the coordination between design engineers, public health specialists, regulatory agencies, land use planners, etc., the more useful will be the assumptions used in designing and executing environmental assessment programs.

The following are a few suggestions for the types of objectives one should consider for an environmental assessment program:

- Assist in the development of new source performance standards.[3]
- Identify potential (perhaps unexpected) pollutants via screening tests of effluent streams.
- Identify control measures (either process modifications or add-on technology) which could reduce concentrations of potential pollutants.
- Design tests to determine the consequences of transferring a pollutant from one medium to another.
- Predict acceptable limits for emission rates using scenarios based on known or assumed pollution impact.

Outline of a Sample Environmental Assessment

The following provides an example of a relatively small-scale environmental assessment program. The project is designed primarily as a paper study which will be used to lay the groundwork for a much more comprehensive assessment.

Preliminary Environmental Assessment of Coal-Fired Fluidized Bed Combustion Process[*]

Objectives and Scope of the Project

The objective of this project is to conduct a preliminary evaluation of the potential pollutants in all variations of the coal-fired fluidized bed combustion process. This will include: (1) identifying all conceivable pollutants which could be emitted from the fluidized bed combustion process; (2) providing an estimate of the concentration levels at which these pollutants could be emitted plus an evaluation of their relative environmental hazard; and, (3) identifying means which could potentially be used to control any pollutants formed at undesirably high levels.

The project can be divided into three tasks each of which is described in more detail below.

1. Identify Conceivable Pollutants - The technical objectives here are twofold:

   a. To review all fluidized bed combustion programs being conducted by either government agencies or private corporations. The aim here is to identify, for each process, key parameters (temperature, flow rate, particle size) which could influence the generation of pollutants.

   b. To identify all pollutants which could be emitted from fluidized bed boilers. Based on the materials involved (coal, bed material, combustion air) and the important process parameters, a list of conceivable pollutants can be generated for each major process. The location of the pollutants (i.e., air, water, solid waste effluent streams) should also be identified.

---

[*] Based on work underway in the Advanced Process Branch of the Energy Assessment and Control Division, U.S. Environmental Protection Agency, Industrial and Environmental Research Laboratory, Research Triangle Park, North Carolina.

2. Specify Important Pollutants - This would involve a more detailed analysis of the fluidized bed process — including calculations and application of data where available — to provide some basis for determining the levels at which the potential pollutants listed in (1) could be emitted from various types of fluidized bed combustion processes.

   The concern here is with factors such as fluidizing velocity, particle size, turbulence, bed inhomogeneity, etc., and the manner in which they will affect phenomena such as vaporization, microscopic catalysis, thermodynamic equilibria, solubility, etc. The object is to use the above types of information (and whatever assumptions are necessary), to provide at least an order of magnitude estimate of the concentrations of various pollutants in the process effluent streams (air, water, and solid waste).

3. Suggest Possible Control Measures - The technical objective of this task is to suggest means for reducing emissions of all important pollutants in effluent streams from fluidized bed combustion processes.

   The first step is to identify what concentration levels of the various pollutants are required to make the effluent streams acceptable. This will include a review of existing and proposed source performance standards and state-of-the-art pollution impact investigations. Various plant sizes will also be considered. Once this is completed, a survey of currently existing and proposed control techniques can be made to assess their compatibility with fluidized bed combustion processes. Control techniques which may be considered include: material pretreatment, process modifications or add-on processes. A ranking system can then be developed to cover the range of "most" to "least" compatible control techniques.

As mentioned previously, the above outline of a sample energy system assessment is a preliminary project aimed at providing the groundwork for a more comprehensive investigation. In addition to updating work in the preliminary assessment, the comprehensive program would likely include tasks such as the following:

- Identification of missing information and the design of a program to acquire such information
- Design and execution of source sampling and ambient monitoring program(s)
- Review and analysis of existing fluidized-bed combustion (FBC) process engineering and cost data
- Determination of emission goals for FBC processes
- Analysis of control efficiency and cost of varying levels of control efficiency
- General program support:
  - Maintenance of a system for storage and retrieval of assessment data
  - Technical review and evaluation of related projects
  - Preparation of reports as required
  - Participation in future program planning.

ENVIRONMENTAL ASSESSMENT REPORTS

Because rapid and efficient technology transfer will be one of the primary benefits of environmental assessments, the reporting of information is an important aspect of the overall effort. A unique and rigorous format for all reports is unwarranted; however, each report, at a minimum, should include the following major topics:

- An introduction to provide perspective on the project
- An explicit statement of the project's goals
- A summary of conclusions and recommendations
- An overview of the activities in the project (including a listing of all value judgments used in making conclusions and recommendations)
- A presentation of the data compiled in the project.

REFERENCES

1. Council on Environmental Quality. Statements on Proposed Federal Actions Affecting the Environment. Fed Reg. 36:1398, January 28, 1971; also, Fed Reg. 36:7724, April 23, 1971.

2. Council on Environmental Quality. Preparation of Environmental Impact Statements, Guidelines. Fed Reg. 38:20550, August 1, 1973.

3. Cuffe, S. T. Development of Federal Standards of Performance. Office of Air Programs, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Presented at U.S. Environmental Protection Agency Stationary Source Combustion Symposium, Atlanta, Georgia. September 19, 1975.

SECTION III

PROCESS CHARACTERIZATION AND WASTE STREAM ANALYSIS

INTRODUCTION

The estimation or compilation of process emissions is usually one of the most important tasks of any environmental assessment. To evaluate the effects of an energy system on the environment, the physical and chemical form of pollutants and the nature of the waste streams (air, water or solid) must be categorized. The purpose of this section is to discuss methodologies and necessary background information that can be utilized to develop a comprehensive understanding of process emissions.

The emission rates of pollutants from the various unit operations are crucial for estimating the sphere of influence of the energy system and for evaluating its potential environmental impact (as discussed in Sections V and VI respectively). Potential emission rates should be determined in the initial stages of development of an energy system because they will often serve as criteria for implementing research and development programs related to the process itself, developing new control technologies, or undertaking environmental health studies to fill data gaps.

The degree to which process emissions studies are pursued is dependent upon the goals of the assessment, which may vary from system to system. In conventional systems, for example, where much data and technical expertise is available, comprehensive assessments can be successfully carried out. Assessments of advanced systems, on the other hand, may require more modest goals which are defined by the availability and reliability of data and/or existing technology.

Regardless of the system complexity, the stage of development, or the projected level-of-effort, all assessments will require the application of a definite methodology based on sound engineering and scientific principles for determining system emissions. This section discusses the activities necessary to develop such an inventory. The intent is to familiarize the reader with principles and techniques necessary to characterize processes and to measure or estimate waste stream compositions.

This section is divided into the following subsections:

- Methodology for Process Evaluation
- Description of Emission Sources in Terms of Unit Operations
- Methods for Determining Emission Rates
- The Influence of Abnormal Operating Conditions.

The activities discussed here must not be performed in isolation; they must relate to the other tasks in the assessment (e.g., the information developed on waste stream compositions should be in a form which is compatible with siting decisions, needs for further control devices, and scale-up projections).

METHODOLOGY FOR PROCESS EVALUATION

The flow chart in Figure 4 outlines a methodology which can be used to gather information on source emissions. The methodology should be applicable to systems at any stage of development. Listed below are brief summaries of the tasks outlined in Figure 4.

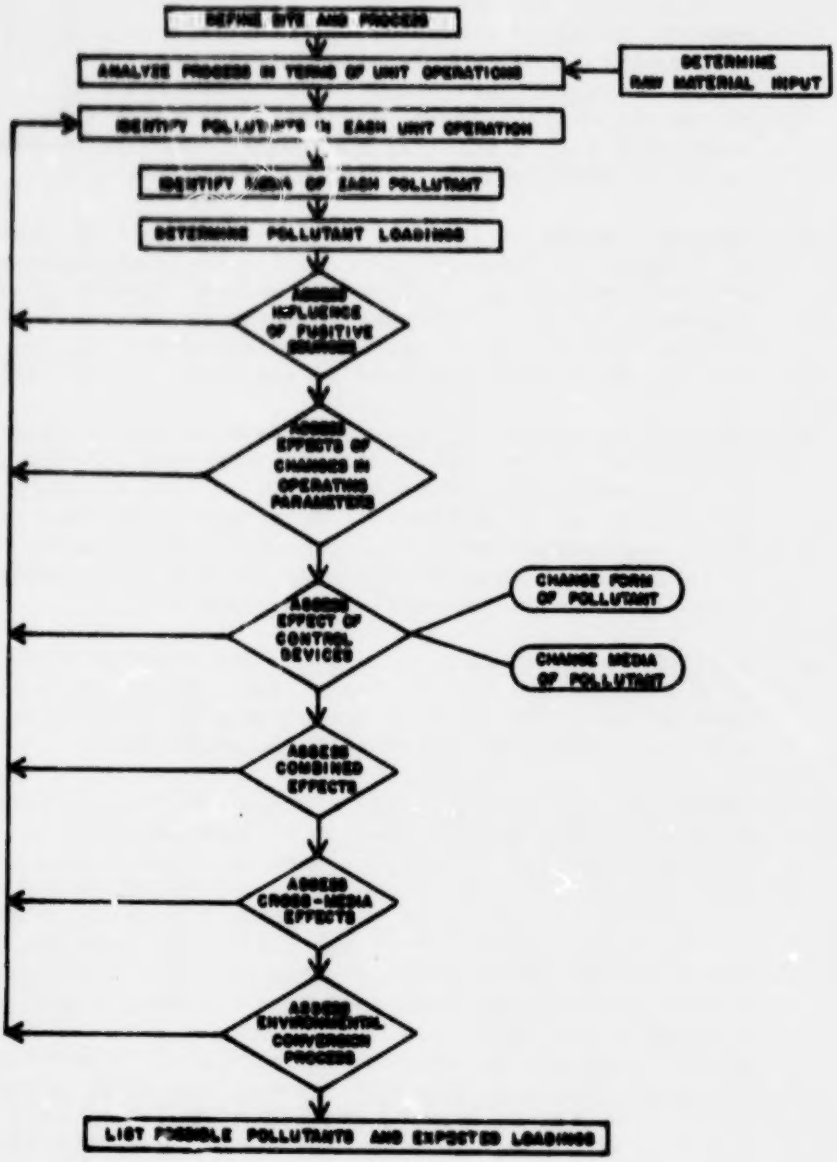

DEFINE SITE AND PROCESS
ANALYZE PROCESS IN TERMS OF UNIT OPERATIONS
DETERMINE RAW MATERIAL INPUT
IDENTIFY POLLUTANTS IN EACH UNIT OPERATION
IDENTIFY MEDIA OF EACH POLLUTANT
DETERMINE POLLUTANT LOADINGS
ASSESS INFLUENCE OF FUGITIVE SOURCES
ASSESS EFFECTS OF CHANGES IN OPERATING PARAMETERS
ASSESS EFFECT OF CONTROL DEVICES
CHANGE FORM OF POLLUTANT
CHANGE MEDIA OF POLLUTANT
ASSESS COMBINED EFFECTS
ASSESS CROSS-MEDIA EFFECTS
ASSESS ENVIRONMENTAL CONVERSION PROCESS
LIST POSSIBLE POLLUTANTS AND EXPECTED LOADINGS

Figure 4. Methodology for process evaluation

- Define Site and Process - In defining the process, topics to be covered include purpose of the system (e.g., space heating, electric power, etc.), materials requirements, development schedule, potential sites, etc. In the early stages of system development, site selection will often be of low priority; relevant geographic features inherently associated with a specific technology, such as proximity to water, can probably suffice to define the site.

- Analyze Process in Terms of Unit Operations - The analysis of a system in terms of basic unit operations insures that the similarities and differences between systems are highlighted. Process breakdowns in terms of unit operations are the core of any process characterization and, therefore, must be thoroughly developed at any level of assessment.

- Identify Potential Pollutants - Based on the chemical composition of the raw materials and pertinent process parameters (temperature, pressure, etc.), a list of conceivable pollutants can be developed. Once these have been identified, engineering and scientific evaluations can be made to determine at what concentration levels these chemicals could exist in various effluent streams.

- Identify Media of Each Pollutant - The eventual destination of the pollutants must be identified. Some compounds may form as vapors in one unit operation but condense in another and hence leave the system with the solid waste.

- Determine Pollutant Loadings - Pollutant emissions and their initial destination can usually be derived directly from the process breakdown, although the means used to determine emission factors will vary from system to system, as well as with the current stage of development. Emission estimates for processes at the conceptual level will necessarily be compiled from calculations or from analogies with unit operations appearing in well-characterized energy systems. For systems at the pilot plant or commercial stage of development, source tests can be performed to accurately measure pollutant loadings. However, even with source test data, estimates may have to be used to predict changes in emission rates resulting from variations in operating conditions. Methods for estimating emissions are discussed in later subsections.

- Assess Influence of Fugitive Sources - Fugitive emissions are sources of pollutants which cannot easily be controlled. These emissions in general are not directly related to process operating conditions (e.g., dust from coal piles or oil shale crushing).

- **Assess Changes in Operating Parameters** - Changes in operating parameters can modify the pollutant output, thus requiring a retesting of the effluent stream for changes in concentration, or for the appearance of new pollutants. For instance, in fossil fuel combustion, the NO_x emissions are dependent on both the operating temperature and excess air. Therefore, if the flame temperature or amount of excess air supplied to the flame is altered, the stack gases should be resampled for changes in NO_x concentration.

- **Assess Effects of Control Devices** - Control devices can change both the media of a pollutant and its toxicity level. The systems planner should be aware of the trade-offs involved in transferring a pollutant from one medium to another. For example, sulfur oxides can be scrubbed from stacks by a lime or limestone slurry to form a sludge. By utilizing limestone scrubbing, the plant generates approximately three times the solid waste it would produce without scrubbing. Hence, reduced gaseous emissions are traded off for an increase in solid waste.

- **Assess Combined Effects** - Combined effects arise when several different unit operations discharge into one effluent stream. In general, combined effects are more important in waste water than in air because wastewater sinks are smaller; hence dangerous concentration levels can build up faster. For example, boiler blowdown, process water, and simple drainage frequently collect in a common water settling pond. Less commonly, plumes from two stacks can combine in the air, depending upon prevailing wind conditions. Combined effects can either have a beneficial or a negative impact in terms of environmental interactions. An example of a beneficial impact would be the combination of alkaline and acidic process wastes to produce a neutral effluent. An example of a negative impact would be the accelerated photochemical oxidation of SO_2 in the presence of hydrocarbons.

- **Assess Cross-Media Effects** - Cross-media effects arise from a pollutant in one media being deposited in the same or modified form in a second media. An example of cross-media effects on a site is the water runoff from a coal pile. The media crossed in this case would be solid to water, and the pollutants could be particulates, or dissolved inorganic or organic chemicals washed from the coal.

- **Assess Environmental Conversion Processes** - Environmental conversion processes occur when a pollutant reacts in some manner in the outside environment. Thus, care must be taken to differentiate between primary emissions and secondary products. An example is the conversion of gaseous SO_2 to solid sulfate particulates after oxidation in the atmosphere. Other chemicals prone to conversion are NO_x, hydrocarbons, NH_3, and sometimes free metals.

The environmental impact includes not only emissions to the environment, but also the effect of resources removed from the immediate surroundings. Factors such as cooling water utilization (with attendant lowering of water levels); on-site mining of coal, oil shale, etc.; or tapping of geothermal wells (resulting in possible seismic and geochemical alterations), are also of environmental concern. As discussed earlier (page 3), this document is primarily concerned with on-site operations; those activities occurring for example at remote mining or waste dumping sites are not discussed at length. However, Sections IV and V discuss, to a limited extent, some of the problems involved with resource utilization due to direct (process dependent) and indirect (related to associated development) causes.

UNIT OPERATIONS ANALYSIS

The first step in the analysis of any energy system is a systems breakdown into the basic unit operations. The unit operations concept in chemical engineering is based upon the principle that widely disparate processes can be reduced to a series of simple physical or chemical operations which are based upon the same engineering practices, regardless of the overall process.[1,2] Common unit operations found in energy systems include but are not necessarily limited to:

- Transportation of gases, liquids, and solids
- Heat transfer
- Chemical reaction

- Screening
- Drying
- Distillation
- Grinding
- Extraction.

The breakdown of processes into their unit operations is common engineering practice. A simplified and limited scheme for classification of unit operations encountered in energy systems is shown in Figure 5 in order to facilitate discussions on the remainder of this Section. The flow chart in Figure 5 is limited to usual on-site activity and hence does not include unit operations for mining or product utilization. However, for processes in which these activities may occur on site (e.g., low Btu gasification may involve on-site product utilization), the on-site flow diagram must be arranged accordingly.

A Sample Unit Operations Scheme

A unit operations flow chart for coal-fired fluidized bed combustion is provided in Figure 6 to illustrate the complexity of a typical system. The numbering scheme identifies the mass flows within the system. Each operation and control unit must be analyzed in terms of input and output streams and operating conditions. The use of unit operations allows a complex process to be described in terms of a series of relatively simple operations, thus focusing attention on the effluent streams from each operation. By tracing emissions to the unit operations, decisions as to where pollution control devices may be needed are simplified.

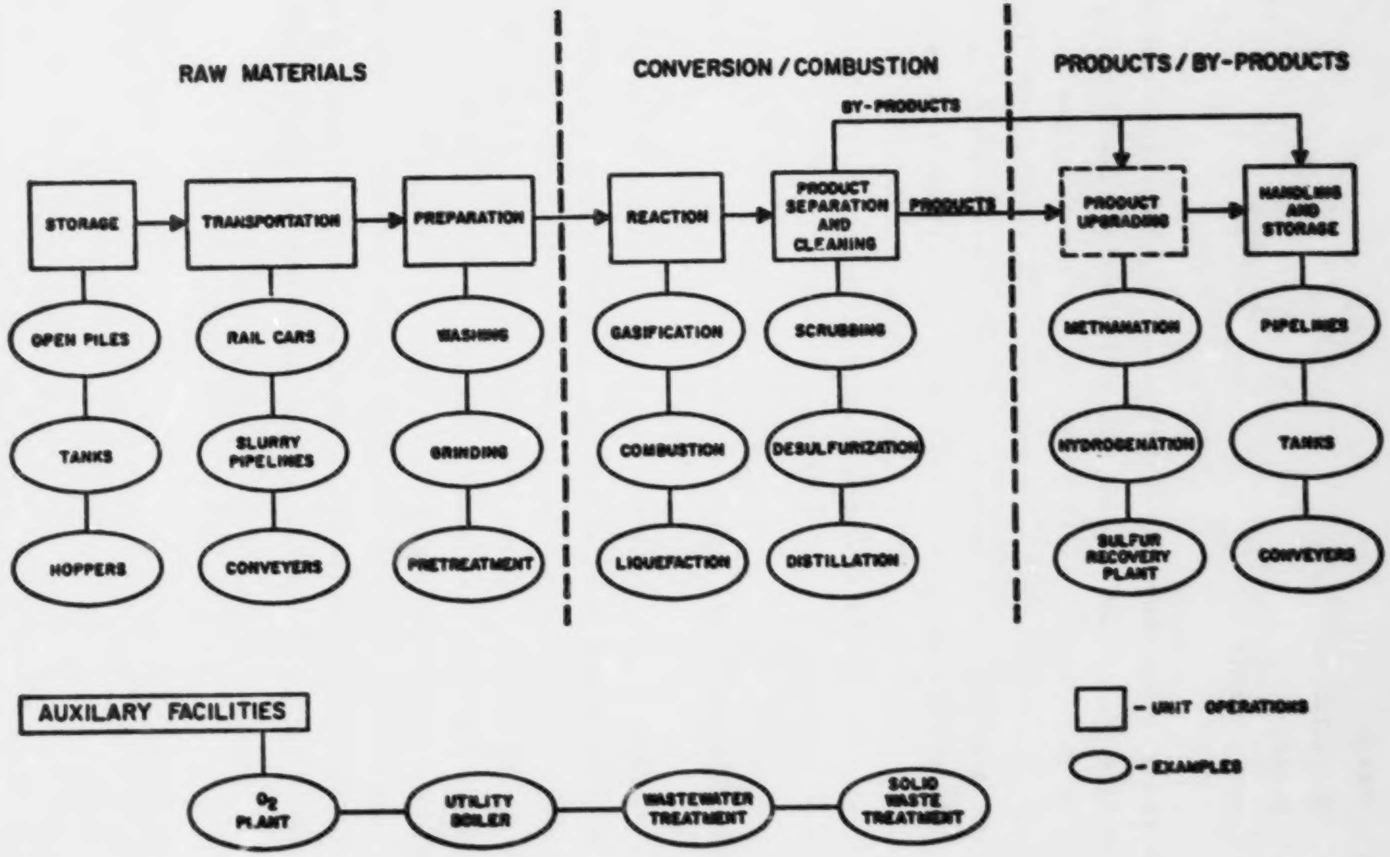


Figure 5. Simplified scheme for unit operations of an energy system

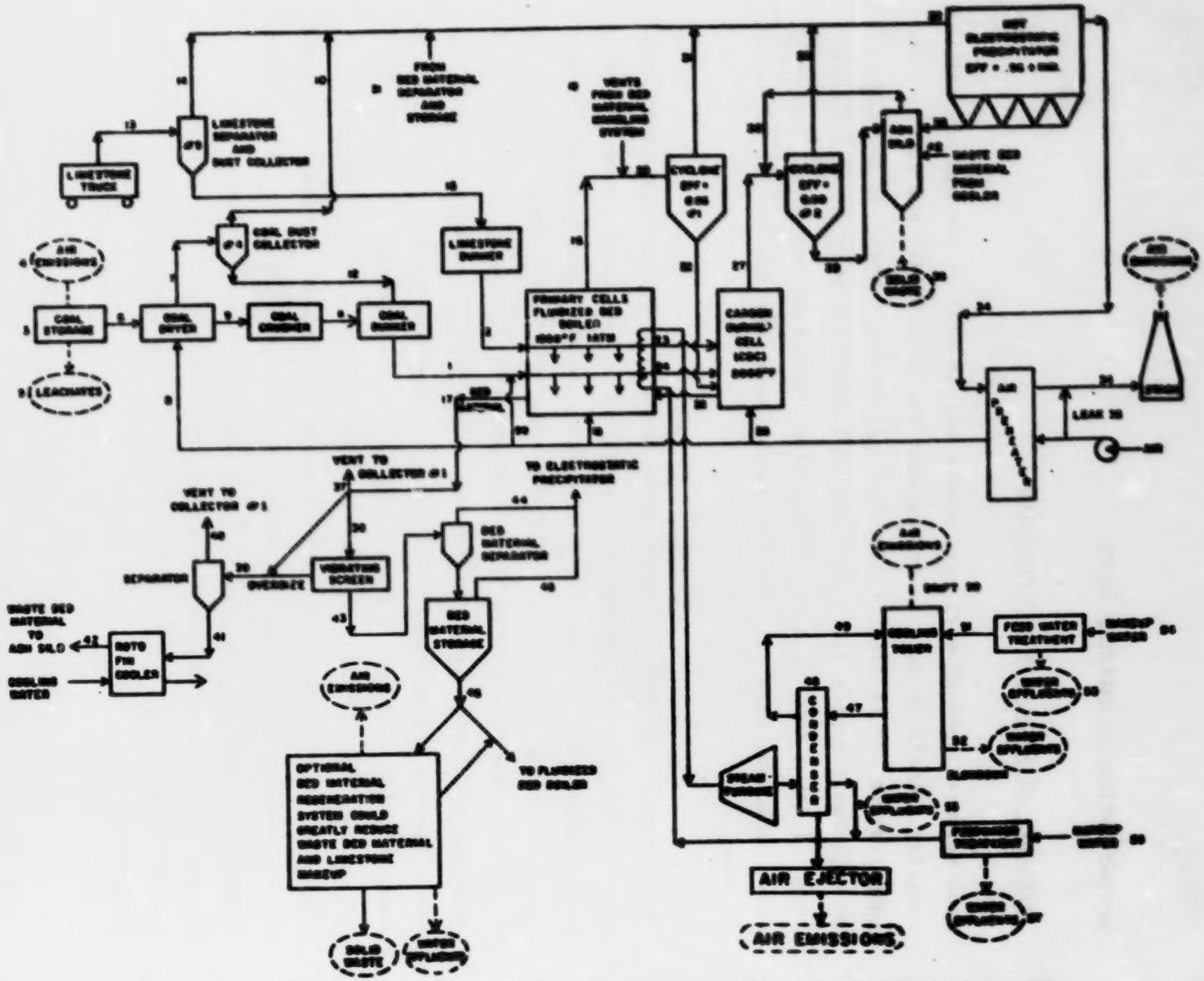


Figure 6. Schematic diagram of an atmospheric pressure fluidized bed combustion system (reference 3)

DETERMINATION OF EMISSION RATES

Inventory of Reactants and Products

Mass balances through each unit operation, as well as through the entire facility, should be made to ensure that the fate of all raw material feed constituents can be identified. To evaluate the overall emission rates of pollutants from a facility, each unit operation must be analyzed in terms of input feed rate and composition, operating conditions (temperature, pressure, physical reaction parameters), and destination of output streams.

To illustrate the type of information needed for preparing mass balances, Table 2 is a partial listing of a waste and input stream inventory which can be compiled for some of the mass flows in the fluidized bed combustion unit shown in Figure 6. For the total inventory, Table 2 would include data for each of the 57 streams shown in Figure 6. In Table 2, all quantities are normalized to the input coal feed. A compilation of this sort, listing solid, liquid, and gaseous mass loading and temperature of each transfer system in the process, is a natural outgrowth of the detailed unit operations flow chart. This information will usually be available from engineering studies and/or measurements already conducted during process feasibility and operating studies. In addition to stream composition outflow, raw material loadings and chemical composition must be ascertained to complete the process mass balance. This process stream characterization is the foundation on which the "inventory" phase of the assessment is built.

So far, the activities required to characterize the process have been those which encompass a standard engineering evaluation and thus are normally carried out before, and perhaps independently of, an environmental assessment. Other tasks involved in an assessment program, such

Table 2. PARTIAL LIST OF MATERIAL FLOWS FROM AN ATMOSPHERIC PRESSURE FLUIDIZED BED COMBUSTION SYSTEM[a]

Input/outflow stream	Material				Gas	Liquid	Temp., °F
	Total	Carbon	Ash	Sulfur			
1. Coal feed to beds[b]	1.0000	0.7120	0.085	0.043	-	-	80
2. Limestone feed to beds	0.2709				-	-	80
3. Coal storage[c]	1940	1390	160	84	-	-	80
4. Air emissions from coal storage	0.0008	0.0005	0.0006	0.0004	-[d]	-	80
5. Coal pile drainage	0.0004			0.000003-0.0006	-	0.078	80
6. Coal feed to dryer	1.0	0.712	0.085	0.043	-	-	80
7. Air emissions from coal dryer before primary control	0.01	0.0071	0.00085	0.00043	1.2	-	160

[a] This information was generated from data in reference 3.

[b] All mass flows are in lbs material/lb coal. A 30 MW FBC facility requires 28,000 lbs coal/hr.

[c] Storage capacity is not a material flow.

[d] Carbon monoxide and hydrocarbons from spontaneous combustion - amount unknown.

as thermal efficiency calculations and mass balances on certain chemical species, may also be carried out during the technical development phase. In addition to mass balances, heat balances should be performed for selected process steps because they are environmentally important in determining which unit operations will generate thermal emissions affecting the ambient surroundings.

The reasons for preparing detailed material balance and heat balance tables are threefold. First, they are a succinct way of presenting process parameters for each unit operation. Secondly, the analysis of input and output streams of each unit operation allows computation of the elemental composition of the effluent streams. Finally, they provide a method of assuring that no significant sources of emissions are overlooked.

Identify Conceivable Pollutants

Various federal, state, and local laws regulate the discharge of specific pollutants to ambient water and air. In addition to these emission limitations, ambient air and water standards have been enacted to protect the integrity of these media. The temporal requirements include limits on hourly, daily, and annual average concentrations and, in some cases, a certain permitted frequency of violation. These regulations are frequently updated and eventually new species will be added to the list of pollutants to be monitored. (Relevant regulations are summarized in Appendix D.)

An environmental assessment should go beyond merely insuring compliance with present legal requirements. It is important to anticipate the influence of future laws and regulations which could limit certain emissions.

Decisions about the relative importance of various process emissions must be based upon their respective concentrations and upon state-of-the-art scientific information about their potential environmental impact. Although specific quantitative source/receptor relationships must be investigated for each system, generalizations based upon experience with operational systems can alert the user to potentially important emissions. The use of other environmental assessments and environmental impact statements on related systems or similar sites can provide valuable sources of information and should always be consulted for background information. (A useful series of preliminary environmental assessments is provided in references 4-10.)

In conceptual, bench scale, and pilot plant assessments where limited waste stream data are available, decisions must be made regarding potentially important emissions and the need for appropriate control devices and/or process modifications to control such emissions. In these cases some knowledge of expected pollutants is necessary to facilitate process acceptability and planning judgments. In assessments of systems at later stages of development, in which comprehensive source test programs can be carried out, knowledge of potential pollutants provides a checklist to insure that no crucial effluents remain undetected.

Figure 7, which is based on a classification scheme for hazardous materials generated in the extraction and processing of coal and oil, illustrates the diversity of conceivable pollutants which could result either directly or indirectly from energy system emissions.[11] Compounds such as carbonyl compounds, hydrocarbons, or phenols, if found, are likely to occur within the various process streams of energy systems. Compounds such as hydroperoxides, nitrosamines, lactones, or halocarbons could form via reactions of process effluents in the ambient environment.

A methodology has been developed for classifying process streams according to their potential for generating harmful chemicals.[11] For each

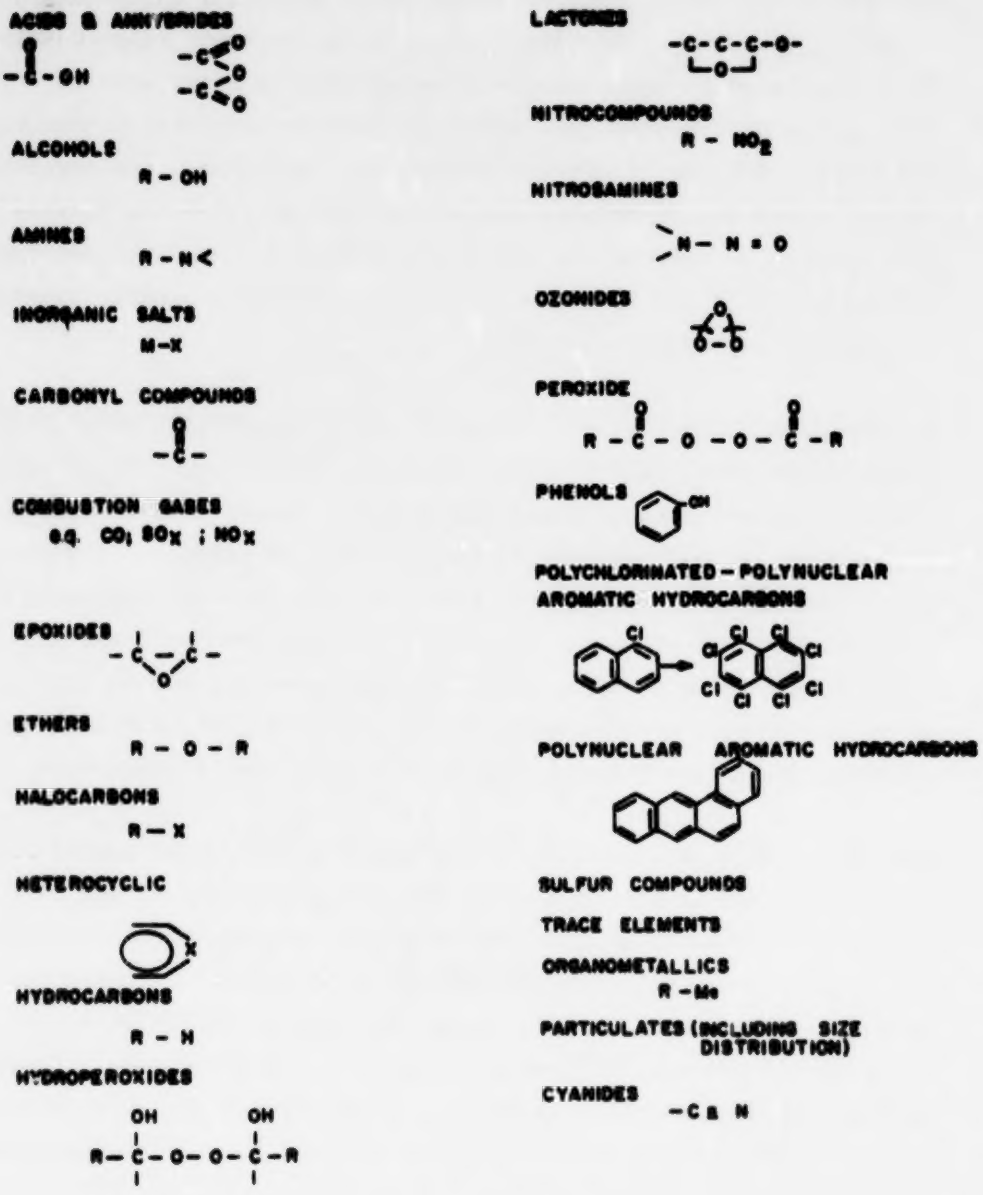


Figure 7. Classification for hazardous materials generated in the extraction and processing of coal and oil

stream, potential pollutants such as those shown in Figure 7 are categorized as: known hazardous (KH), suspected hazardous (SH), known present (KP), and suspected present (SP).

These ratings are then combined for each effluent stream in descending order of importance, as KP-KH, KP-SH, SP-KH. A grid is prepared, listing the waste stream from each unit operation versus the pollutant class. The grid is then filled in with the pollutant rating for each waste stream as shown in Figure 8. The results of this analysis provide a convenient display of the potential pollutant emissions for each unit operation. This allows the system planner an easy means of identifying both the type and source of potential pollutants.

Determination of Emission Rates

Source Tests - Source tests involve the actual measurement of the chemical composition and flow parameters of effluent streams. They are an essential part of any overall environmental assessment program because they are the only means of providing definitive answers to the question of which pollutants are being emitted at what rates from which sources. A methodology for conducting source tests on an energy system is outlined on the diagram shown in Figure 9. This methodology can be applied to any unit operation of an energy system. The two major aspects of this methodology are sampling and analysis. Appendix A contains a general discussion of the approach which should be followed in utilizing the sampling and analysis techniques which are presently used in source testing.

The level of effort which is needed to adequately characterize a process and its effluent streams will depend on both the developmental status of the system and the goals of the assessment.

Estimates - Although comprehensive source tests for specific effluents are the most definitive way of compiling an emissions inventory, in many

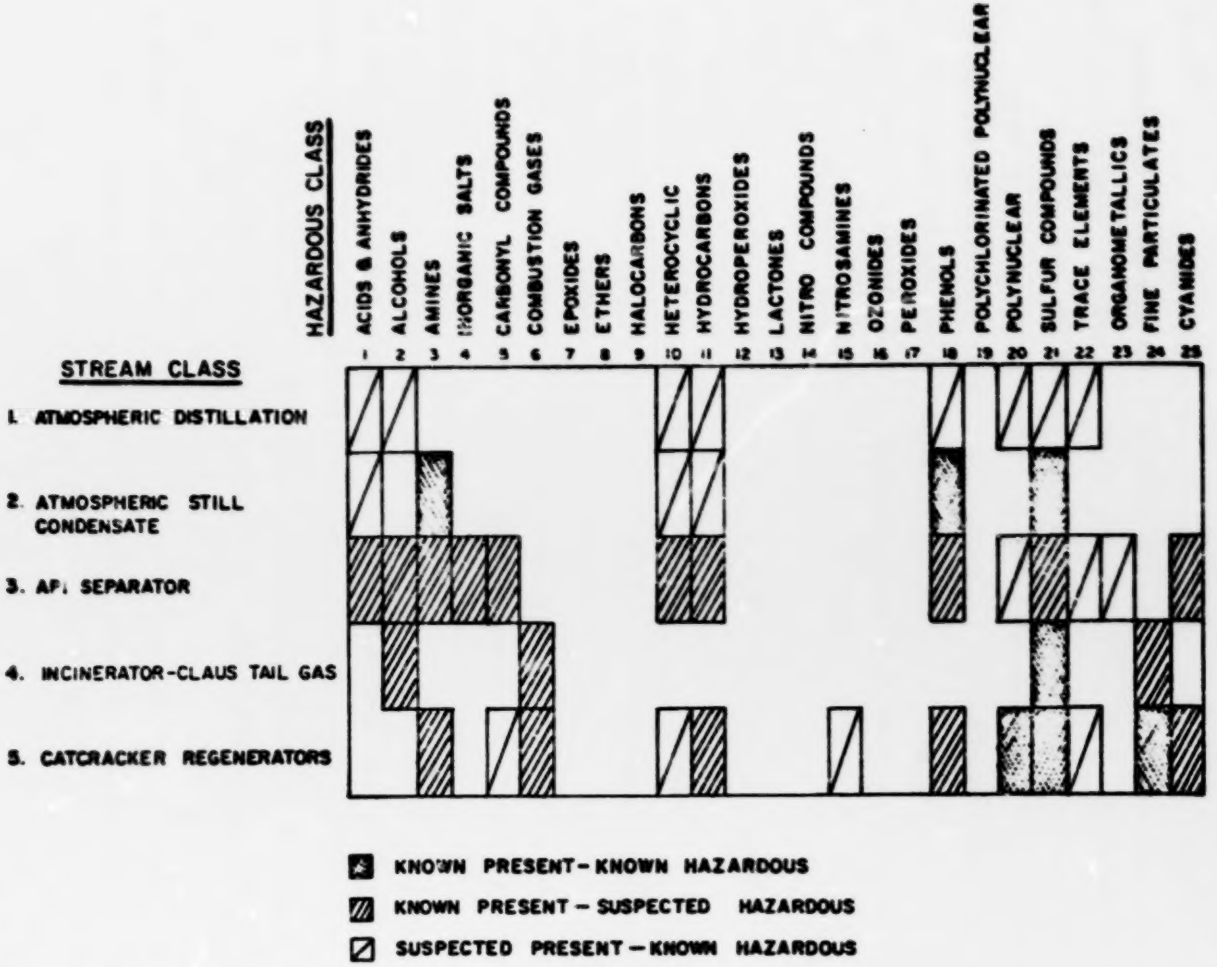
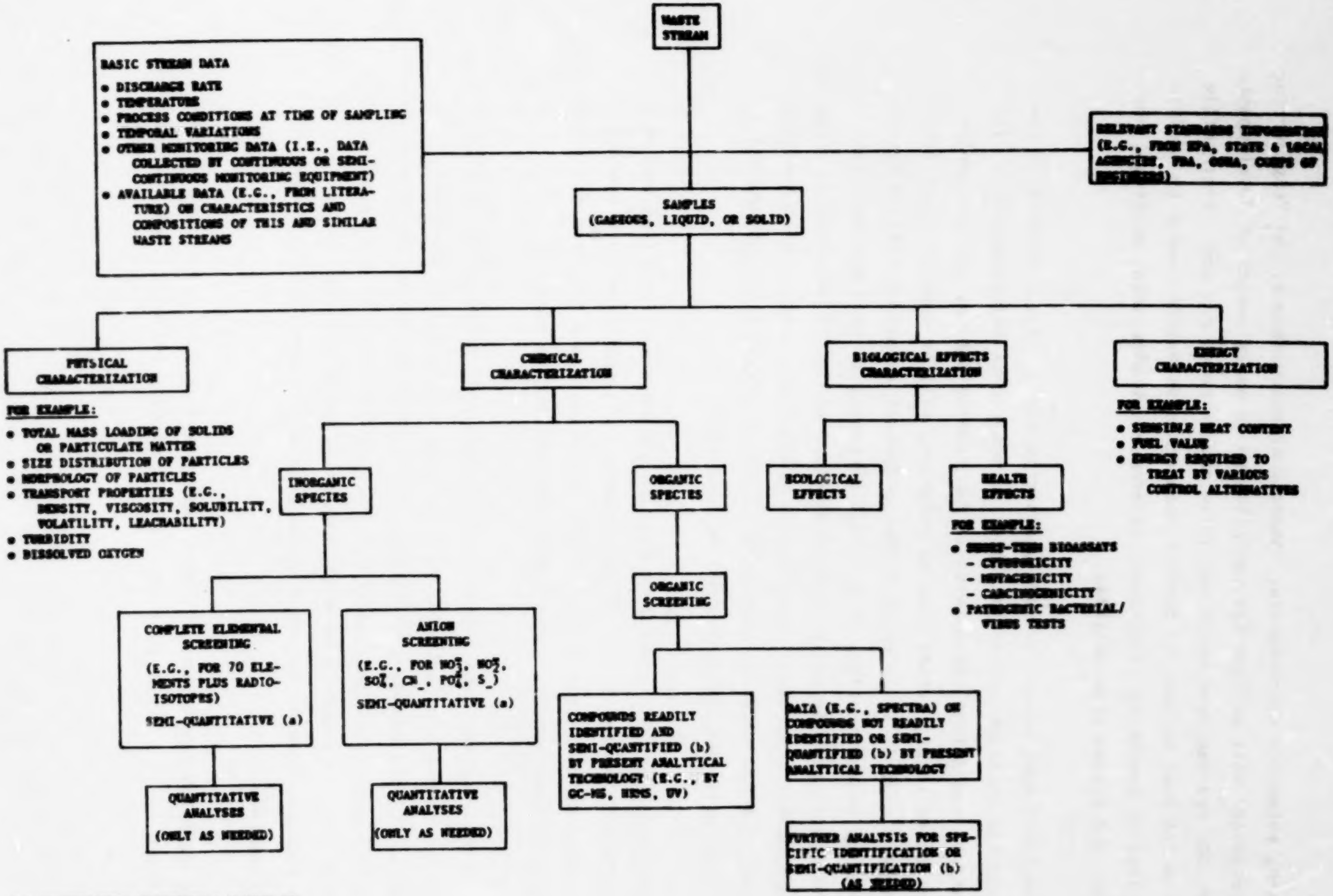


Figure 8. Ranking scheme of the hazardous classes of pollutants in effluent streams in a petroleum refinery


WASTE STREAM
BASIC STREAM DATA
• DISCHARGE RATE
• TEMPERATURE
• PROCESS CONDITIONS AT TIME OF SAMPLING
• TEMPORAL VARIATIONS
• OTHER MONITORING DATA (I.E., DATA COLLECTED BY CONTINUOUS OR SEMI-CONTINUOUS MONITORING EQUIPMENT)
• AVAILABLE DATA (E.G., FROM LITERATURE) ON CHARACTERISTICS AND COMPOSITIONS OF THIS AND SIMILAR WASTE STREAMS
RELEVANT STANDARDS INFORMATION (E.G., FROM EPA, STATE & LOCAL AGENCIES, FDA, OSHA, CORPS OF ENGINEERS)
SAMPLES (GASEOUS, LIQUID, OR SOLID)
PHYSICAL CHARACTERIZATION
FOR EXAMPLE:
• TOTAL MASS LOADING OF SOLIDS OR PARTICULATE MATTER
• SIZE DISTRIBUTION OF PARTICLES
• MORPHOLOGY OF PARTICLES
• TRANSPORT PROPERTIES (E.G., DENSITY, VISCOSITY, SOLUBILITY, VOLATILITY, LEACHABILITY)
• TURBIDITY
• DISSOLVED OXYGEN
CHEMICAL CHARACTERIZATION
INORGANIC SPECIES
COMPLETE ELEMENTAL SCREENING (E.G., FOR 70 ELEMENTS PLUS RADIO-ISOTOPES) SEMI-QUANTITATIVE (a)
QUANTITATIVE ANALYSES (ONLY AS NEEDED)
ANION SCREENING (E.G., FOR NO$_3^-$, NO$_2^-$, SO$_4^=$, CN$^-$, PO$_4^=$, S$^=$) SEMI-QUANTITATIVE (a)
QUANTITATIVE ANALYSES (ONLY AS NEEDED)
ORGANIC SPECIES
ORGANIC SCREENING
COMPOUNDS READILY IDENTIFIED AND SEMI-QUANTIFIED (b) BY PRESENT ANALYTICAL TECHNOLOGY (E.G., BY GC-MS, HRMS, UV)
DATA (E.G., SPECTRA) ON COMPOUNDS NOT READILY IDENTIFIED OR SEMI-QUANTIFIED (b) BY PRESENT ANALYTICAL TECHNOLOGY
FURTHER ANALYSIS FOR SPECIFIC IDENTIFICATION OR SEMI-QUANTIFICATION (b) (AS NEEDED)
BIOLOGICAL EFFECTS CHARACTERIZATION
ECOLOGICAL EFFECTS
HEALTH EFFECTS
FOR EXAMPLE:
• SHORT-TERM BIOASSAYS
- CYTOTOXICITY
- MUTAGENICITY
- CARCINOGENICITY
• PATHOGENIC BACTERIAL/VIRUS TESTS
ENERGY CHARACTERIZATION
FOR EXAMPLE:
• SENSIBLE HEAT CONTENT
• FUEL VALUE
• ENERGY REQUIRED TO TREAT BY VARIOUS CONTROL ALTERNATIVES

(a) QUANTITATIVE TO WITHIN A FACTOR OF 2 OF THE TRUE CONCENTRATION.
(b) QUANTITATIVE TO WITHIN A FACTOR OF 10 OF THE TRUE CONCENTRATION.

Figure 9. Diagram summarizing the types of basic stream data to be collected for environmental assessments (taken from reference 12)

cases, selective measurements, theoretical calculations, and "engineering experience" will suffice for technologies in early stages of development. Even for systems upon which extensive source tests are made, engineering estimates must be used to predict changes in emissions caused by modifications in operating conditions, alternate raw materials, start-up, shutdown, and system abnormalities.

A decision must always be made whether to attempt a calculation of the pollutant emission concentration or to measure it experimentally. Frequently, conditions encountered in functioning systems are so complex that measurement, rather than calculation, will be more cost-effective. However, even if it is decided that pollutant emissions will be determined by source testing, it is still necessary to estimate pollutant loadings to provide background information needed in determining sampling requirements. If emission rates are calculated, instead of actually measured, the calculations should build from a simple base and proceed through more complex tasks only as necessary.

Worst Case Analysis - Emission factors and emissions compilations exist for only a limited number of pollutants, unit operations and systems.[13] In cases where emission factors are unavailable and the need for source tests is questionable, worst case analyses can be used.

In worst case analyses, it is assumed that the entire amount of the element or chemical of interest will be released to the environment. The impact of this maximum emission is then compared to some arbitrary standard (legal, scientific, social — see Section VI). If the impact of the worst case is shown to be environmentally acceptable for the pollutant of concern, then it is not necessary to apply more complex estimation procedures.

Two examples of the use of worst case analysis will prove useful. The first step in a worst case analysis of mercury emissions from a fluidized bed coal combustion apparatus is to calculate the maximum concentration of mercury in the lowest heating value coal. This will determine the maximum flow of mercury into the combustor per unit of heat output. It is then assumed that all the mercury is vaporized and emitted from the stack. Knowing the flow rate of flue gas, an emission rate for mercury can be calculated. This rate is then compared to the maximum allowed emission rate (if one exists). It can also be used in simple atmospheric diffusion models to predict an ambient concentration which can then be compared with some standard.

Worst case analysis can also be used when a trace element may form several different compounds, each having a different level of toxicity and, hence, environmental concern. Here the compound having the highest level of toxicity should always be assumed and the emission rate compared to the appropriate standard. Analyses of this type can often eliminate the need to perform expensive and time consuming measurements.

OTHER PROCESS CHARACTERISTICS OF INTEREST

The preceding discussion has been concerned with the normal operating conditions of the system. However, an environmental assessment must determine the effects of abnormal conditions, such as start up/shut down, load swings, and accidents.

Emissions during these conditions must be compared with normal system emissions to determine their relative importance. The possibility of producing new pollutants under abnormal operating conditions must also be considered. For example, one might expect that emissions of polynuclear aromatic hydrocarbons, the result of incomplete combustion, will be higher during start up or shut down than during normal operating conditions of a combustion system. However, it must be determined whether the conditions of start up or shut down are long or frequent enough to generate significant levels of polynuclear aromatic hydrocarbons. This consideration will be of more concern in an energy generating facility used for swing loads than in a base load facility.

As abnormal operating conditions are quite system dependent, it is impossible to discuss all possible abnormal events and their consequences in a general document such as this. The most economical way to insure that all operating conditions have been considered is through the use of checklists which itemize various possible operating modes and the process parameters which may change in switching from mode to mode.

REFERENCES

1. McCabe, W.L., and J.C. Smith. Unit Operations of Chemical Engineering. 2nd ed. McGraw-Hill. N.Y. 1967.

2. Foust, A.S. Principles of Unit Operations. John Wiley and Sons. N.Y. 1960.

3. Pope, Evans, and Robbins, Inc. Multicell Fluidized-Bed Boiler: Design Construction and Test Programs. Office of Coal Research, U.S. Department of the Interior, Washington, D.C. Report Number OCR-90-INT-1. August 1974.

4. Cowherd, C., M. Marcus, C.M. Guenther and J.L. Spigarelli. Hazardous Emissions Characteristics of Utility Boilers. U.S. Environmental Protection Agency, Raleigh, N.C. Publication Number EPA-650/2-75-066. July 1975.

5. Magee, E.M., C.E. Jahnig, and H. Shaw. Evaluation of Pollution Control in Fossil Fuel Conversion Processes: Koppers-Totzek Process. U.S. Environmental Protection Agency, Raleigh, North Carolina. Publication Number EPA-650/2-74-009-a. January 1974.

6. Evaluation of Pollution Control in Fossil Fuel Conversion Processes: Synthane Process. U.S. Environmental Protection Agency, Raleigh, North Carolina. Publication Number EPA-650/2-74-009-b. June 1974.

7. Evaluation of Pollution Control in Fossil Fuel Conversion Processes: Lurgi Process. U.S. Environmental Protection Agency, Raleigh, North Carolina. Publication Number EPA-650/2-74-009-c. July 1974.

8. Evaluation of Pollution Control in Fossil Fuel Conversion Processes: CO_2 Acceptor Process. U.S. Environmental Protection Agency, Raleigh, North Carolina. Publication Number EPA-650/2-74-009-d. December 1974.

9. Evaluation of Pollution Control in Fossil Fuel Processes: Bi-Gas Process. U.S. Environmental Protection Agency, Raleigh, North Carolina. Publication Number EPA-650/2-74-009-g. May 1975.

10. Bombaugh, K.J. E.C. Cavanaugh (Radian Corporation), and A. Jefcoat (EPA). A Systematic Approach to the Problem of Characterizing the Emission Potential of Energy Conversion Processes. (Presented at The 80th National Meeting of the AICHE. Boston, Massachusetts. September, 1975.)

11. Cavanaugh, E.C., C.E. Burklin, J.C. Dickerman, H.E. Lebowitz, S.S. Tam, and G.R. Smithson. Potentially Hazardous Emissions from Extraction and Processing of Coal and Oil. U.S. Environmental Protection Agency, Raleigh, N.C. Publication Number EPA-650/2-75-038. 1975.

12. Tucker, W.G., S.T. Bunas, J.A. Dorsey, J.A. McSorley and M. Samfield. Environmental Assessment Guideline Document. Draft Document. Industrial and Environmental Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, N.C. May 1975.

13. Compilation of Air Pollutant Emission Factors. Second Edition. U.S. Environmental Protection Agency. Publication Number AP-42. April 1973.

SECTION IV

ESTIMATE POLLUTION FROM ASSOCIATED DEVELOPMENT

INTRODUCTION

The development of an energy system at a particular location can potentially induce changes in population, economic activity, land usage, and life style. These changes can produce identifiable environmental effects which should be included in any overall assessment. The manner in which the new facility can influence the extent of secondary growth that may occur, as well as the timing of such growth, is the subject of this section. The section has two major objectives:

- To formulate a methodology for projecting the magnitude of the induced changes in population and economic activity resulting from a major energy project
- To formulate a methodology for evaluating the environmental effects associated with these changes.

The overall influence of these activities on the environment is labeled "indirect pollution."

The methodology for projecting the magnitude of induced changes in population and economic activity has three major elements:

- Identification of development patterns that are most likely to occur
- Formulation of employment and population multipliers to be used in growth projection

Preceding page blank

- Projection of natural resource requirements (e.g., land and water resources) and human resource requirements (e.g., public services) that are associated with the identified growth and development patterns.

The methodology for evaluating potential environmental effects is aimed at developing indicators of environmental impact and measures of qualitative change. In some cases, it will be possible to project emissions or effluents that are likely to result directly from induced growth. Where this is possible, the information can then be used as input into an air or water predictive model and an actual change in ambient quality can be identified. In other cases, however, the impact will not be so straightforward and must be defined in terms of affected animals, land, or water resource use, per se. This second category of impact provides an indication of additional environmental effects that could occur under certain conditions. For example, land-use alteration resulting in changes in water runoff patterns could affect ground or surface waters, or disruption of vegetation may increase fugitive dust emissions from bared soil.

METHODOLOGY FOR PROJECTING INDUCED GROWTH

General Approach

Each energy project is viewed as causing growth directly and indirectly in employment and population within the project area. Growth will generally be associated with at least three major phases of the project: the construction phase, the prototype plant operation stage, and the mature industry phase. Induced growth will require the commitment of land and water resources to housing, transportation, and public services for the new and expanded residential, commercial, and industrial sectors. At a minimum, it is desirable to identify the major spatial patterns or areas in which growth is likely to occur.

The environmental effects associated with induced growth will impact across air, water, and land as effluents and emissions are generated, and as existing resources are committed for alternative uses.

Elements of Assessment Process

The process described above can be viewed in terms of six major elements which together comprise a methodology for assessing indirect pollution associated with advanced energy development. These elements are:

- Establishment of a regional data base
- Identification of key developmental phases of the project
- Formulation of alternative growth projections, including
    - Projection of direct employment associated with each developmental phase
    - Projection of indirect or induced employment associated with each development phase
    - Projection of total population increase associated with direct and induced employment in each developmental phase
- Identification of alternative spatial allocations in which induced growth is most likely to occur
- Identification of growth in support facilities, services and associated land and water resource requirements
- Evaluation of environmental impacts upon air, water, land, and noise associated with alternative projections of phased, spatially allocated growth.

This six-element assessment process is depicted in Figures 10 and 11. Figure 10 illustrates the first three elements in which alternative regional projections of induced growth are formulated. Figure 11 uses the data from Figure 10 as input into a growth allocation and impact evaluation process.

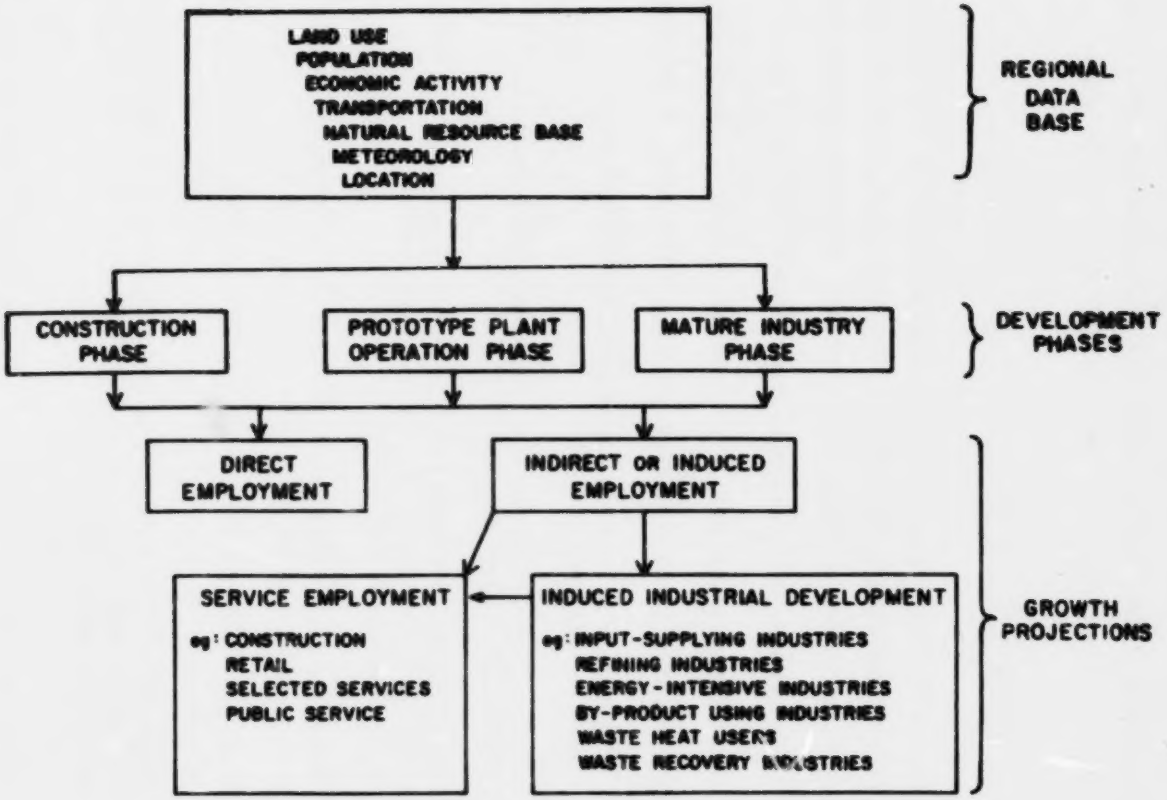


Figure 10. Methodology for projections of induced growth and development

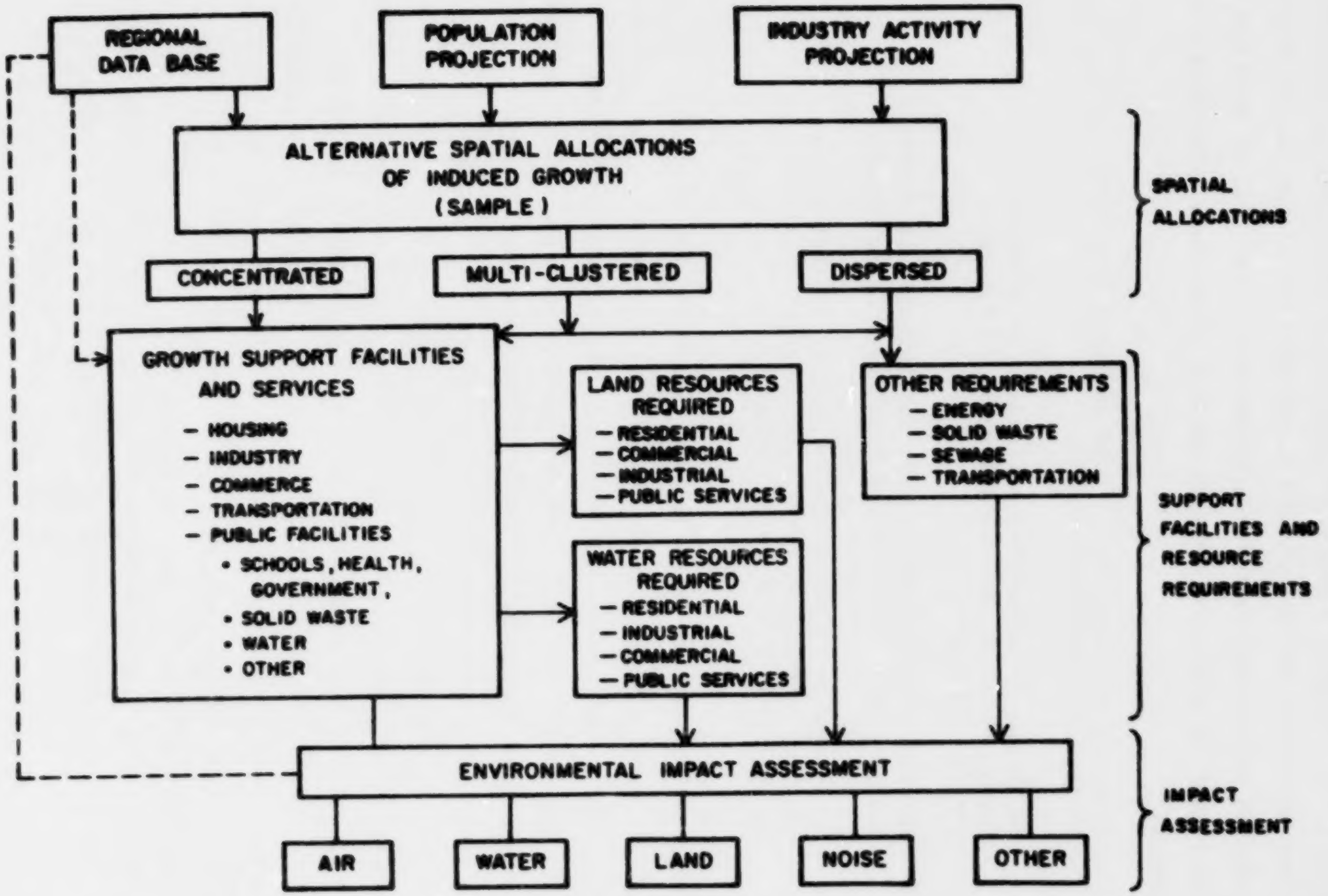


Figure 11. Methodology for growth allocation and impact evaluation

Constraints Upon Assessment

In view of the extensive amount of information necessary to evaluate indirect pollution and the uncertain reliability of the projected growth and spatial allocation estimates, an extensive analysis of indirect pollution should be conducted only in certain situations, including the following:

- Projects resulting in a rapid and/or fluctuating increase in population
- An influx of population sufficient to severely burden existing natural and human resources or service systems
- Key resources in the ambient environment are either highly sensitive to growth or already under stress
- A project is likely to induce growth in industries that are associated with high pollution discharges or with major landform disturbance.

In the following section the six major elements are described, and key questions to be addressed in the assessment are identified. It should be noted that analytical techniques for evaluating indirect pollution effects are in initial stages of development and may require refinement for application to a specific environmental assessment project. Thus, for certain of the elements, an analytical approach may be suggested but not fully developed. In other cases, growth projection may require extensive, often unavailable, data as input for the analysis. In cases where input data is unavailable, it may be desirable to formulate a number of alternate scenarios based on expert opinion. This alternate scenario formulation permits analysis to take place in the face of considerable uncertainty. One overall purpose of secondary pollution effect assessments should be to identify situations in which the indirect effects can reasonably be anticipated to violate an environmental law or regulation. In anticipation of such situations, action may be taken to mitigate effects through such measures as improved land use planning, improved construction and land management practices, and phased expansion of public services.

Discussion of Individual Assessment Elements

In this section the six elements of the secondary effect measurement process are reviewed. The key questions requiring analysis are posed, and methods applicable for use in analysis are discussed.

Establishment of a Regional Data Base - To evaluate the potential for induced industrial development in an area in which an energy system may be located, one must first know the baseline socioeconomic conditions. Key factors which will affect the potential for induced development and for which data should be obtained include: proximity to raw materials and other inputs, transportation and transmission considerations, distance from existing population centers, proximity to market, sociopolitical and legal considerations, federal policy, and existing land use controls. For many of these factors data will be available to evaluate the induced industrial development potential of the area.

Identification of Key Project Development Phases - Each energy system is viewed as possessing at least three distinct developmental phases within which induced population and economic growth are likely to occur.

- Construction Phase - characterized chiefly by the influx of construction workers; by additional employment in service industries linked to the increase in construction activity; by increased population (e.g., families) associated with the influx of new workers; and by land, water, transportation, and other public service requirements associated with the increase in population.

- Prototype Plant Operation Phase - normal operation of the completed plant will occur here, characterized by a relatively stable population associated with plant and plant-induced employment, and by relatively stable land, water, and service requirements.

- Mature Industry Phase - in which national policy, technological advancement, and relative prices and supplies of alternative energy sources foster the growth of the energy system in question. This phase is the most difficult to characterize. It is expected that a mature energy industry will have the greatest potential for attracting associated industries. However, when or where such growth will occur is difficult to ascertain.

The duration of each phase should be estimated, and the manpower requirements for each phase identified by the project developer. These estimates can be based on previous experience, if available, or on analogies with similar industries. In addition to aiding in projections for induced growth, these estimates may also help identify the phase which produces maximum environmental stress, thus allowing for proper planning to minimize the environmental impact.

Alternative Growth Projections - In view of the uncertainties involved in projecting growth in population and economic activity, it will be desirable to pose alternate scenarios concerning the extent and type of growth that may occur. Growth projection consists of a three-step process: estimation of direct employment, projection of induced employment, and total population projection. These steps are discussed separately below. In all areas, it may be desirable to pose a range of growth estimates: low growth, based on low employment and population multiplier effects; moderate growth; and extensive growth, based on large multiplier effects.

Estimation of direct employment - Estimation of the manpower requirements for project construction and operation should be obtained from the developer. It will be valuable for the direct employment estimation to be based upon a plant construction and operation schedule in order to ascertain whether employment will be relatively fixed or fluctuating in total magnitude. The temporal nature of the direct employment increase has implications concerning such factors as whether employees will bring their families; where they will live (e.g., mobile homes or newly constructed housing in the immediate vicinity of a project or in a nearby urban center, etc.); and whether increased public service burdens will be temporary or permanent in nature. Similarly, the nature of the increase is indicative of whether or not population-support facilities and services will be provided, and of the extent to which service employment will be generated. It is also necessary to ascertain what percentage of direct employment may be recruited from within the resident population, and what percentage may be due to the immigration of new workers.

Projection of indirect employment - The major categories within which indirect employment will be generated are:

- Service industries that are created to support the operations of the energy system. This includes equipment repair and servicing, as well as other special, skilled operations.
- Other primary manufacturing industries that could be attracted by the presence of a new market for the specialized products which serve as energy system inputs, by industries using or refining energy system by-products, by materials-recovery plants, by plants utilizing waste heat, or by plants using the energy produced on-site.
- Secondary employment in population-support services and activities including housing construction, retail and selected services, and government.

It will be necessary to ascertain how much additional employment is likely to be generated within the project area as a result of plant construction and operation. Traditional planning techniques, such as economic base theory and input-output analysis, have been utilized in many studies to derive multipliers for estimating induced service employment.

Because both export base and input-output analysis are based on historical relationships within the local economy, consideration must be given to the fact that they may fail to adequately consider more dramatic changes in the local economy. Thus, it may be necessary to define base year conditions according to economic relationships observable within a multi-county area or region. Similarly, it may be necessary to define alternate scenarios of future industrial growth based on expert opinion given the many constraints involved in analysis.

Projection of total population - The direct and induced employment generated by the energy project will result in an increase in total population as workers move into the project area with their families. A typical approach used in estimating population increase is to assume that each new worker constitutes a new household containing "x" persons per household.

Alternative Spatial Allocations of Growth - It will be necessary to identify alternative patterns or major areas within which population growth and/or economic activity may be concentrated. As discussed earlier, certain of the location-related factors which entered into the decision-making process for the energy project itself are likely to be significant considerations for attracting other uses or industries.

For example, significant factors influencing residential development within local areas in the vicinity of the project will include: proximity to the proposed plant site (in trip time) thus reflecting the existing transportation network, presently existing public services and facilities, characteristics of existing housing stock, availability of land suitable for development, land costs, and amenity considerations. Such factors should be used in formulating a general approach for defining local capture rates applicable in calculating increases in local populations.

A major difficulty involved in assessing industrial development potential is that the bulk of industrial development is more likely to be associated with a mature energy industry. Thus, to a great extent, industrial development potential is related to the potential for expansion within the energy industry itself.

Where the energy project being assessed is only one of a number of such projects being proposed within the same region or multi-county area, it may be necessary to consider the synergistic effect that more than one project will have upon induced growth patterns.

Support Facilities and Resource Requirements - The support facilities which will be needed to serve the increased population caused by industrial growth include housing, industrial and commercial buildings, transportation systems, and various public agencies such as schools, solid waste and water treatment, health care, etc. Some of the resource requirements needed to support these facilities are summarized briefly below.

Land - A gross estimation of land area required for the induced growth may be obtained by relating land area to population size. Classical planning studies which have examined the relation between population and land devoted to different uses are given in references 1-3.

Water - A gross estimate of the water requirements associated with the induced growth may be obtained by projecting water consumption for different components of the induced development (i.e., residential, industrial, commercial, institutional, and public).[4-6] An alternate method of estimation is to obtain a local per capita water consumption figure, and then multiply per capita use by the projected increase in population. In the absence of a local per capita estimate, the national municipal per capita average could be applied or modified as appropriate to the region.

Sewage - An estimate should be made of the amount of municipal sewage that will be generated by the induced growth. This is usually done by taking a percentage of water demand, although alternative methods are also possible.[6] The capacity and level of treatment of existing sewage systems should be assessed, and additional system requirements estimated.

Solid waste - The municipal solid waste generation resulting from the induced growth should be estimated, and compared to the capacity of existing solid waste facilities in order to estimate additional service requirements.[7]

Transportation systems - Gross estimation of the number and distribution of trips should be made. One minimal approach would be to obtain the local per capita trip factor and apply it to the projected increase in population. The alternative spatial allocation projections and the existing transportation network capacity should also be evaluated in order to identify additional roadways or linkages that may be required. An additional reason for evaluating the projected allocations and the existing network is to assess whether projected patterns will serve to maximize or minimize the need for automobile travel.

Energy - The gross energy requirements of the induced growth should be estimated in order to determine if additional energy sources will be required to serve projected local and regional demand. One approach would be to obtain estimates of average local energy usage for residential usage, and to apply Standard Industrial Classification energy consumption coefficients for commercial and industrial land uses.

Environmental Impact Assessment - Once the growth projections have been made, the next step is to evaluate the environmental impact which this growth may cause. This involves measuring or estimating pollutant emissions from various sources, aggregating these emissions to generate a "burden projection." Based on these "burden projections," potential changes in environmental quality can be assessed. This methodology for evaluating environmental effects is discussed below in more detail.

METHODOLOGY FOR EVALUATING ENVIRONMENTAL EFFECTS

General Approach

This section will first introduce and briefly summarize the methodology for the evaluation and assessment of potential environmental effects from associated development. A more general discussion of environmental assessment methodologies appears in Section VI. The methodology presented here has been generalized to be applicable to analysis of air, water, land, and other environmental impacts. Each of these impacts is then discussed in greater detail following the general methodology. The methodology for assessing environmental effects is diagrammed in Figure 12. Input includes the regional data base (population, land use, environmental quality, economic activity, etc.), growth and development projections, and alternative land use plans. As a first step, a "burden projection" should be determined utilizing the input data base, new source inventory, and established burden factors. This "burden projection" estimates the upper limit of assumed emissions, effluents, or land usage.

The source inventory identifies the potential major new contributors to the overall burden. Burden factors are generally the rates at which particular types of sources have historically contributed or are projected to contribute emissions or effluents to the environment. This first step thus identifies the pollutant-related substances, the sources of such substances, the rates at which they are produced, and the total burden produced of each substance. A total burden should be determined for the three previously identified phases of development: construction, prototype plant operation, and mature industry.

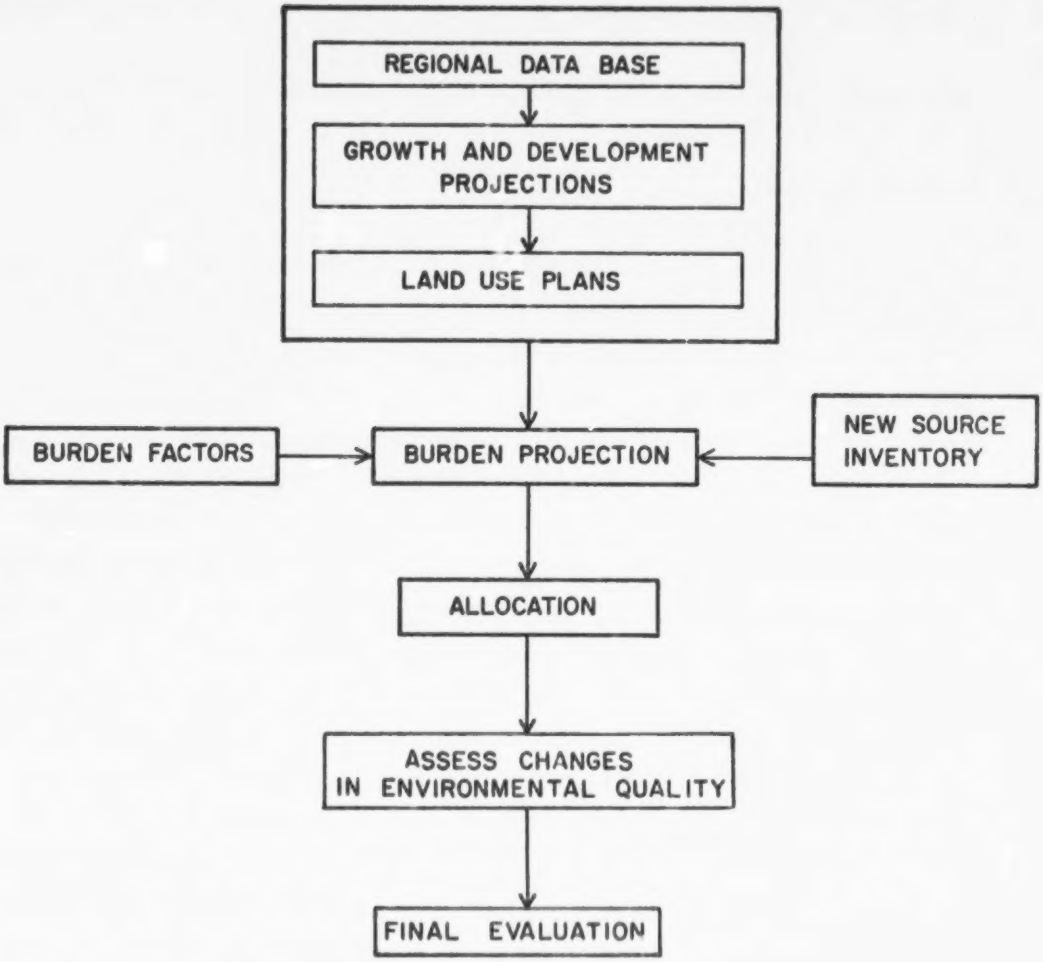


Figure 12. Methodology for assessing environmental effects as a result of induced growth

Burden projections are then allocated within the project area. A qualitative assessment follows, using analytical models designed to yield projections of concentrations and distributions of the key pollutants or pollution-related substances.[8] A wide variety of modeling techniques are available. Selection would be based primarily on data availability and level of accuracy required.

The following discussion provides a simplified example of the use of this methodology. (Detailed descriptive guidelines for analysis of each individual environmental impact follow this brief example.) The purpose in this example is to predict the induced increase in the use of highway vehicles (mobile sources) as a result of system construction. Establishing 1975 as the base year, and 1977 as the year for projection, the scenario for a simple hydrocarbon air quality assessment is tabulated as follows:

Year	Hydrocarbon emission factor, grams/mile[9]	Vehicle miles traveled, VMT	Hydrocarbon emission burden, kilograms
1975	6.4	1,000	6.4
1977	4.7	2,000	9.4

The daily VMT, within some defined boundary, is projected to double by the end of the 2-year period because of the construction activity associated with a new energy system. The total emission burden allocated to this area increases from 6.4 kilograms per day in 1975, to 9.4 kilograms per day for the 1977 projection, despite the fact that hydrocarbon emission factors have actually decreased. Assuming that existing hydrocarbon concentrations have been measured or estimated, and that other basic data is known, a simple proportional model would be capable of estimating the impact of the hydrocarbon concentration, which is mainly in forming photochemical oxidants. The use of these simple proportional models has been recently reviewed,[10] and the reader is referred to this reference for a more detailed discussion of their application. Although the accuracy of proportional modeling is limited, its use is recommended as an indicator of trends in air quality in areas now maintaining National Ambient Air Quality Standards (NAAQS). If preliminary analysis indicates the possibility of a violation, a more extensive analysis must be undertaken. In this case, the hydrocarbon concentration in 1977 would equal 9.4/6.4 times the 1975 concentration. The evaluation would determine if the estimated concentration is or is not acceptable.

Air Quality Impacts

In many cases, energy projects are being proposed for rural locations which are not now violating air quality standards, and where continued growth at pre-energy project levels would not exceed standards. Rather than undertake an extensive air quality assessment for all projects, a preliminary screening procedure is recommended. The objective of the screening procedure would be to identify areas in which existing laws, regulations, standards, or plans are likely to be violated as a result of energy project-induced growth. For projects in which secondary effects include large population increases and extensive development patterns (both normally associated with large increases in VMT, and thereupon high projected burdens of CO and HC), a more extensive analysis would be required.

Based on preliminary emissions burden projections, various air quality models could be selected for assessment of impacts, ranging from simple proportional modeling to complex diffusion procedures. Proportional modeling would be a useful screening tool, and would be applicable to areas where sophisticated techniques could not be used due to the lack of required data. More extensive modeling efforts would be indicated if violation of standards appeared likely.

A step-by-step outline for the evaluation and assessment of air quality impacts follows:

1. Collect basic data. Data requirements for the assessment of air quality consists of the following:

   - Air Quality Data
   - Meteorology
   - Vehicular Use Characteristics
   - Stationary Source Inventory.

2. Identify future sources of emissions from growth and development projections and land use plans. The major sources could be classified by the following categories:

   - Industrial Process - consisting chiefly of new industrial point sources in high-emission associated industries

   - Fuel Combustion - emissions from both point and area sources due to the direct combustion of fuels, including new residential space heating

   - Transportation - emissions contributed directly from transport vehicles, including automobiles, based largely on projected motor vehicle activity and VMT

   - Incineration - emissions resulting from waste disposal methods

   - Miscellaneous - sources characterized by intermittent emissions which at certain times may be significant, and which are frequently regional or highly unique.

3. Develop and apply regionally-specific emission factors to each source category.

4. Utilizing data and parameters identified in steps 1-3, determine emissions burden projections. Projections need not be completed for all pollutants if ambient levels are presently well below standards and projected source rates are minimal. Projections should be completed for each growth phase as determined previously.

5. Input emissions burden for each pollutant into air quality diffusion models. Evaluate for impacts and compare pollutant concentrations with acceptable air quality standards.

Water Quality Impacts

Water is considered polluted if it is no longer suitable for its intended use (domestic, industrial, or other). Federal guidelines have been established to enable the states to maintain the use and quality of surface waters.[11] These standards include limitations on effluents from newly constructed industries, pretreatment standards for discharge into municipal treatment plants and discharge standards for toxic substances. A further discussion of water standards can be found in Appendix D.

The following is a step-by-step guide for the evaluation and assessment of water integrity impacts:

1. Collect basic data. This information, primarily an inventory of the natural environment, is required for a comprehensive analysis of present and projected water quality conditions and impacts.
    - Geologic Features and Characteristics
    - Topography
    - Climatology and Meteorology
    - Hydrology - surface and subsurface
    - Vegetation and Wildlife.
2. Identify future sources of effluent substances from growth and development projections and land use plans. The major sources can be classified by the following eight categories:[12]
    - Municipal Wastes - include all wastes that are collected and transmitted through community systems of sanitary sewers. Both commercial and domestic sanitary wastes, and the wastes discharged by manufacturing plants to public sewer systems, fall into this category

- Other Urban Wastes - include the waterborne residues of urban activity that do not routinely enter the system of sanitary sewers. Direct runoff from urban areas, overflows, and bypass of waste treatment plants caused by combined storm and sanitary sewers, and the unassimilated drainage of septic tanks comprise the major elements of the category. In addition, runoff from parking lots and highways falls into this category[13]

- Industrial Wastes - include the separately discharged wastes of manufacturing. Both process waters and manufacturers' cooling waters fall under this heading

- Electrical Generation Wastes - include the discharge of heated cooling waters of thermal power generating stations, the presence of radioactivity from nuclear-fueled power plants, and the particulate fallout and acidity associated with fossil-fueled power plants

- Agriculture - includes the effects of runoff on siltation of streams, organic and nutrient loadings originating with livestock, concentrations of pesticides and herbicides from the runoff of agricultural lands, and salinity that occurs with leaching and evapo-transpiration in the irrigation process

- Mining - includes siltation from scarred lands, acid drainage from reaction of water with exposed mineral seams, pumping of brine deposits, and introduction of undesirable minerals and ions

- Spills - include the deposit in water of any polluting or toxic material as the result of accident

- Other - includes water management in the highly regulated streams of the west, and the promotion of sedimentation by construction and the effects of transportation (principally navigation), including stream dredging.

3. Develop and apply regionally-specific effluent factors to each source category. However, it is the goal of the Federal Water Pollution Control Act of 1972 to eliminate discharge of pollutants into navigable waters.

4. Utilizing the data and parameters identified in steps 1-3, determine effluent projections. These projections need not be completed for all parameters listed in step 3. Selection criteria are based upon a determination of existing and proposed conditions for the local surroundings.

   Projections should be determined for each phase of the energy system development, as defined previously. Impacts should be clearly separated as groundwater or surface water effects. In addition, the effluent projection should be allocated among surface water and groundwater.

5. Insert effluent projections into water quality model to estimate water quality. Evaluate impacts and compare pollutant concentrations with acceptable water quality standards and goals from such sources as the "Federal Water Pollution Control Act Amendments of 1972." (See Appendix D.)

Land Impacts

An influx of people and industries into an area as a consequence of energy system development would cause a significant increase in developed land density and an accompanying impact on land use. Increased land usage includes schools, roads, commercial buildings, housing, and services. Acreage for vegetation and wildlife habitat would decrease, solid waste generation and disposal problems would be aggravated, visual effects degradation would be associated with development, and topographic alterations — caused by development — would occur. In addition, these land impacts can accelerate degradation of other environmental sectors.

The following presentation is a step-by-step guide for the evaluation and assessment of land impacts caused by the induced effects of energy system development:

1. Collect basic data. This information, generally in the form of a comprehensive land use inventory, will provide a base for analysis of land use changes and impacts.

2. Identify future users of developed land from growth and development projections and land use plans. The users of the land will be the source of land burden. (Land demand requirements were discussed in an earlier section.)

3. Develop and apply regionally-specific burden factors to each source category. These factors will identify land changes and impacts with respect to the following:

    - Solid waste generation
    - Alteration of topography (degradation of natural features)
    - Visual effects (degradation of scenic quality)
    - Disruption of vegetation and wildlife habitat.

4. Utilizing data and parameters identified in steps 1-3, determine total land burden projection. Projections should be measured for each growth phase. A comparison between the burden measurements of the four topics listed in step 3 and the total land resources committed for development will be a useful evaluation tool.

5. Evaluation of land impacts appears difficult due to the subjective nature of criteria. At best, an indication of the extent of land impacts can result. Some distinguishable land effects which result in, for instance, alterations of topography, will cause measurable impacts on water or air. These effects are to be treated in the consideration of the affected medium.

Noise Impacts

Noise effects are dependent upon intensity and frequency; the impact is a function of the duration of occurrence and the distance from the source.

The following presentation is a step-by-step guide for the evaluation and assessment of noise impacts:

1. Collect basic data. This information is used to determine the ambient noise level. The ambient noise level is the composite of airborne sound from the many sources associated with a given environment. Additionally, intrusive noise levels, those which are superimposed on the ambient noise (typically a high-level, short-term phenomena), are also to be determined.

2. Identify major noise sources from growth and development projections and land use plans. The sources of intrusive noise levels can be classified as either mobile or site-related. These sources collectively produce the ambient background noise levels.

3. Develop and apply regionally-specific noise factors to each source category. These factors would be defined in terms of intensity, duration, distance, and frequency.

4. Combine data and parameters identified in steps 1-3 to determine ambient and intrusive noise levels. Projections should be completed for each growth phase as defined previously. Projections should be allocated among potential receptors.

5. Insert noise level projections into a quality assessment model to estimate noise intensity. Intensities at potential receptors are evaluated for overall assessment of impact. Intensities are compared with designated use at receptor site for compatibility.

Other

The same general approach would be applicable in examining other environmental effects, such as heat and radiation effects. In view of the similarity of approach, these effects have not been discussed separately. The reader is referred to Appendix E for a bibliography covering general environmental issues and analyses.

REFERENCES

1. Bartholomew, H. Land Uses in American Cities. Cambridge, Massachusetts, Harvard University Press, 1955.

2. Manuel, Allan D. Trends in the Value of Real Estate and Land, 1956-66. Manuel, Allan D. Land Use in 106 Large Cities. Gustafson, R.H. and R.B. Welch. Estimating California Land Values from Independent Statistical Indicators. In: Three Land Use Research Studies. Prepared for National Commission on Urban Problems, Washington, D.C. Report Number 12. 1968.

3. Niedercorn and Hearle. Recent Land Use Trends in 48 Large American Cities. In: Internal Structure of the City, Bourne (ed.). New York, Oxford University Press, 1971.

4. Forecasting Municipal Water Requirements. Hittman Associates, Inc., Columbia, Maryland. NTIS Publication Number PB-190275. 1969.

5. Porges, R. Factors Influencing Per Capita Water Consumption. Water and Sewage Works. Vol. 104:199-204, May 1957.

6. Linnaweaver, F.P., Jr., J.C. Geyer, and J.B. Wolff. A Study of Residential Water Use. Study Prepared for the Federal Housing Administration. Washington, D.C. U.S. Government Printing Office. 1967.

7. Macon County Solid Waste Management System Analysis. Roy F. Weston, Inc., Project No. 40.00 for State of Illinois, Illinois Institute for Environmental Quality. April 1974.

8. Ott, W., J.F. Clarke, and G. Ozolins. Calculating Future Carbon Monoxide Emissions and Concentrations from Urban Traffic Data. U.S. Public Health Services, Publication Number 999-AP-41, Cincinnati. 1967.

9. Compilation of Air Pollution Emission Factors. Office of Air and Water Quality Programs, U.S. Environmental Protection Agency, Research Triangle Park, N.C. Publication AP-42. September 1973.

10. Patterson, R.M., D.A. Bryant, and A.H. Castaline. Photochemical Oxidant Modeling Techniques Applicable to Highway Systems Evaluation, Final Report, Volume I. Prepared by GCA/Technology Division, Bedford, Massachusetts. For: U.S. Environmental Protection Agency, Contract No. 68-02-1367, Task Order No. 14. July 1975.

11. Proposed Criteria for Water Quality - Volume I. U.S. Environmental Protection Agency. Washington, D.C. October 1973.

12. Reitze, A.W., Jr. Environmental Law. 2nd Edition. North American International Press. 1972. p. 47.

13. Pitt, R.E. and G. Amy. Toxic Materials Analysis of Street Surface Contaminants. U.S. Environmental Protection Agency. Publication Number EPA-R2-73-283. 1973.

SECTION V

ESTIMATING THE SPHERE OF ENVIRONMENTAL INFLUENCE

INTRODUCTION

Comprehensive environmental assessments of energy systems will require that the information obtained from the process characterization, waste stream analysis, and evaluation of indirect development be combined with site characteristics to provide an estimate of the extent to which a particular facility will influence the surrounding area. The reliability of the estimate of the sphere of environmental influence will depend upon the accuracy with which the data collected under the procedures outlined in Sections III and IV can be quantitatively related to emission rates, operating characteristics, and source locations. An equally important activity is the selection of relevant site parameters which describe the meteorological, hydrological, and topographical characteristics which play a significant role in pollutant transport processes. Finally, a model must be found or developed which relates both source and site data to predicted ambient concentration levels. This section presents a methodology for estimating the sphere of influence in four steps:

- Obtain process emission characteristics
- Identify pathways for pollutant transport
- Survey site characteristics
- Use predictive models.

METHODOLOGY FOR ESTIMATING THE SPHERE OF INFLUENCE

Figure 13 provides a flow diagram depicting a methodology for predicting the sphere of influence of an energy system. The methodology parallels the physical processes which influence pollutant dispersion. One must first understand the traits of the emission source -- emission rates, temperatures, types of chemicals, etc. This information is necessary for the next step which is to identify pathways for pollutant transport. Details regarding the climatology, topography, etc. of the site are next needed to assess the relative importance of various pathways and to provide input data for predictive models. The last step is to select appropriate models which can predict the resultant changes in ambient concentrations. Each of the steps is discussed in more detail below.

Process Emission Characteristics

The determination of the environmental sphere of influence for a particular energy system begins with the designation of those unit operations that emit pollutants. For fossil-fueled power plants, operations such as fuel handling, storage, and combustion are of primary concern. If the effects of induced growth are of paramount interest, a particular aspect of this growth, such as road construction or residential heating, may be singled out for special study. Once this designation has been made, the process characteristics associated with the given unit operation should be investigated to ascertain those factors which exert a controlling influence upon pollutant disposal. This description includes flow rates, temperatures, emission factors, and waste stream configurations. Completion of this step in the methodology provides the set of emission rates for all pollutants of interest, including heat and noise, to each sector of the environment (air, water, and land). The process characterization should also be constructed to provide information regarding the chemical activity and physical nature of the pollutant in question. This data will be crucial in the later studies of pollutant transport.

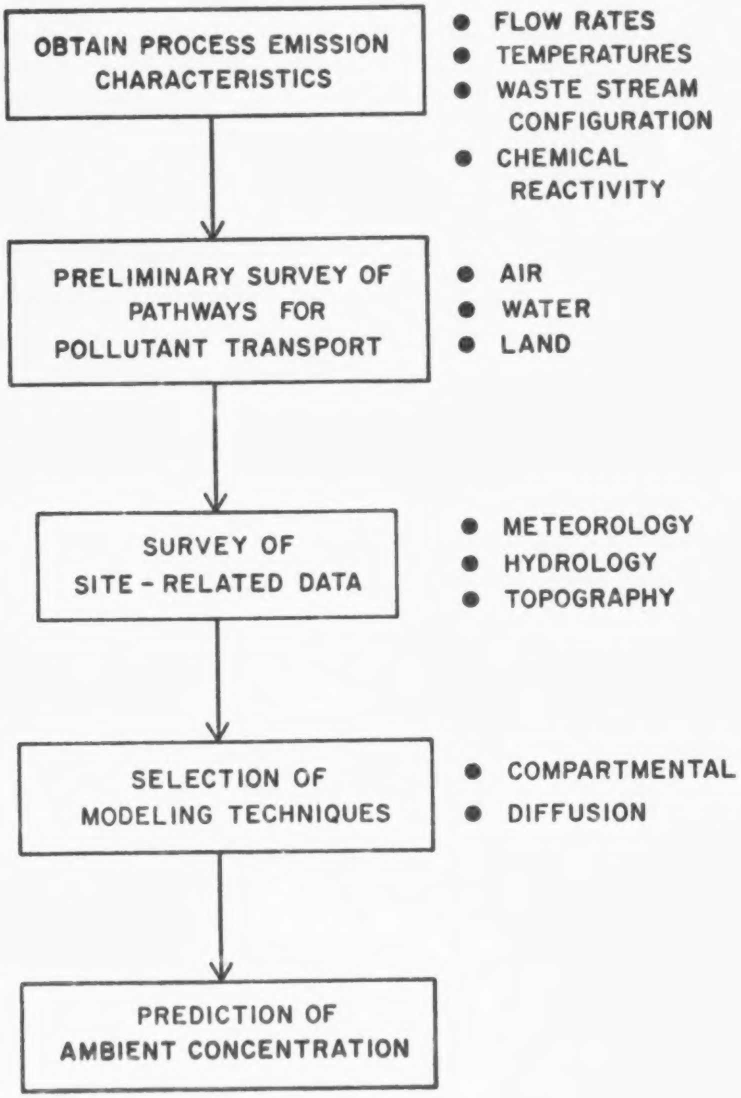

OBTAIN PROCESS EMISSION CHARACTERISTICS
● FLOW RATES
● TEMPERATURES
● WASTE STREAM CONFIGURATION
● CHEMICAL REACTIVITY
PRELIMINARY SURVEY OF PATHWAYS FOR POLLUTANT TRANSPORT
● AIR
● WATER
● LAND
SURVEY OF SITE-RELATED DATA
● METEOROLOGY
● HYDROLOGY
● TOPOGRAPHY
SELECTION OF MODELING TECHNIQUES
● COMPARTMENTAL
● DIFFUSION
PREDICTION OF AMBIENT CONCENTRATION

Figure 13. Methodology for predicting the sphere of influence

Source Configuration - The first step in the characterization of pollutant emissions is the specification of the actual physical configuration of the source. For atmospheric point source emissions, the most significant physical parameters are the stack height, stack diameter, gas exit velocity, and gas temperature. These parameters, together with the ambient temperature, are used in the calculation of buoyant plume rise, which is responsible for a greater degree of plume dilution due to an increased effective stack height.[1] These plume rise parameters are also required in the characterization of vapor and water droplet emissions from cooling towers.[2] Other required source characteristics are the locations of each point source and the location and spatial extent of each area source. It is important to study the relationship of each source to nearby structures in the area because of its possible influence in the process of plume rise retardation or downwash.[3]

Source configuration is also a prime factor in the analysis of pollutant release to a body of water. For instance, waste material may be introduced, after some degree of purification, to a fast moving stream where it would be adequately diluted after some distance down the stream. Alternatively, a pollutant could be discharged to a large pond where suspended solids could settle to the bottom before the effluent is allowed to flow into a neighboring body of water. The geometrical configuration of release points is especially critical in the assessment of thermal pollution impacts.[4]

Cross media transport can play an important role in pollutant dispersion. A pollutant emitted into one sector of the environment may indirectly find its way to another. A substance originally emitted into the atmospher may reach a lake by means of wet or dry deposition through the air-water interface. Even if deposition takes place on the ground, the material may still reach the water by means of overland flow or erosion. The burial of solid wastes can cause water pollution problems due to ground water contamination. In some cases, gaseous substances may be emitted from the water surface to the atmosphere because of chemical reactions of primary pollutants; this often happens in many settling ponds.

Emission Rates - The determination of the emission rate is based upon an emission factor for a particular process obtained from actual tests or engineering estimates. The emission factor for area sources is only a representative value and may actually be a strong function of other variables such as windspeed. For example, surface mining activities in support of new energy systems or the storage and disposal of raw materials or solid wastes could add to fugitive dust problems. Other parameters important in the fugitive dust emission process include soil moisture, surface roughness, vegetative cover, and soil texture. A wide range of pollutant emission factors are available through EPA Publication AP-42.[5]

An emission rate may represent an average over a number of different time periods depending upon the type of assessment being undertaken. For example, if a given sector of the population is sensitive to short-term episodes of elevated concentrations, an hourly distribution of emission rates would be of interest,* whereas long-term effects, such as wet and dry deposition of pollutants in the vicinity of a source, would require only average annual emission values. For particulate emissions, it may be necessary to specify separate emission rates for different particle size classes due to their different deposition properties and the strong functional dependence between respiratory impact and particle size.

In the specification of emission rates, care should be exercised to insure that the resultant emissions data possess an adequate degree of spatial resolution. While this condition presents no problem for point source emissions, significant errors may result if area source boundaries are not properly delineated. In the EPA National Emissions Data System (NEDS), area source emissions from industrial, commercial, residential, and transportation sectors are specified on a county-wide basis. Since county-wide totals do not give the necessary resolution for model application, these emission rates must be allocated to subcounty areas according to criteria such as population, employment, and vehicle miles traveled. Area sources associated with a particular facility, such as materials storage, should be characterized in even more detail.

---

*This could be of importance, for instance, in energy systems used primarily for peak loading.

Physical and Chemical Properties of Emissions - Once the emission rate for a pollutant has been calculated, an effort must be made to characterize the physical and chemical properties of the emitted substance. The physical state of the pollutant (solid, liquid, or gas) will exert considerable influence upon its subsequent transport properties. An even more important consideration is the chemical behavior of a substance in the air, water, and land sectors. While a complete chemical characterization of a pollutant is not always required, standard properties such as density, solubility, and potential chemical reactivity should always be noted.

Survey of Pathways for Pollutant Transport

When all relevant source data have been gathered, a preliminary survey of pollutant transport pathways should be conducted. This survey will determine the focus of subsequent site-data collection activities (see Figure 14). For example, there is no need to construct an extensive meteorological data base for the area in question if pollutant releases are made exclusively to water systems. Similarly, if water quality problems are projected to be of only secondary importance (resulting, for example, from atmospheric deposition of particulates and gases), then hydrological parameters can be specified in much less detail than meteorological variables.

In a characterization of the sphere of environmental influence, it is necessary to consider all the avenues of pollutant transport through the

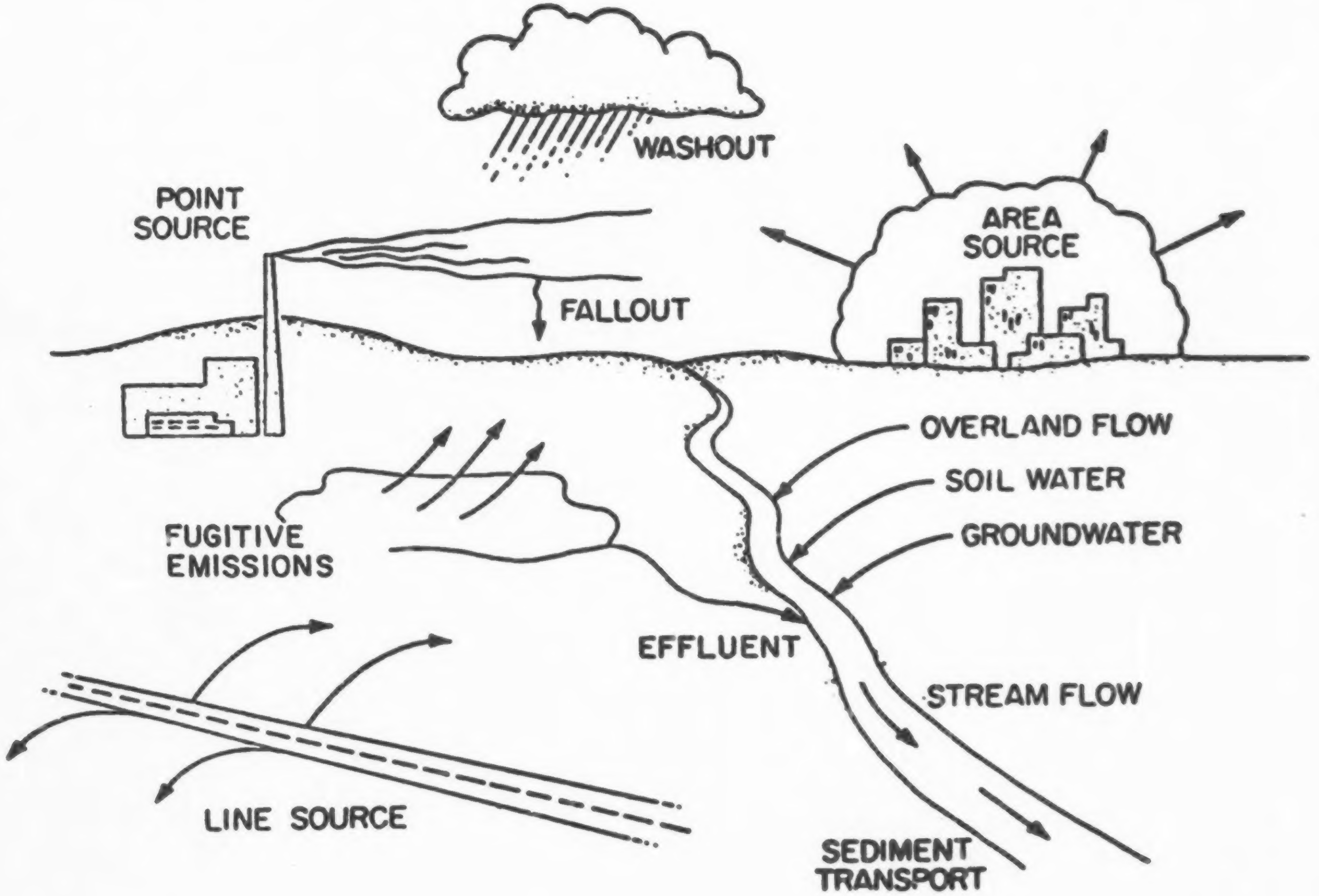


Figure 14. Pollutant emissions and transport pathways

environment. Although the rate of movement of a particular constituent through one sector of the environment might be relatively small, over a long period of time, the net effect of this process could be considerable. A total environmental assessment will require the analysis of a wide range of transport times and distances. Predictions of atmospheric transport must be carried out on a scale of tens of kilometers over a time span of minutes or hours. On the other hand, an estimate of pollutant migration through the soil involves distances on the order of feet and transport times of months or even years.

Survey of Site-Related Data

Once the potential impact areas have been delineated through the preliminary survey, the gathering of site data should begin. These site reports will provide a determination of the general characteristics of the area, including average wind speed, watershed drainage patterns, and the relationship between both source location and dimension to that of nearby topographical features.

This section outlines some of the more significant site characteristics which play a role in the transport of pollutants. These factors will be grouped into the following categories: topography and vegetative cover, climatology, hydrology, and potential for chemical and biological transformation.

Topography and Vegetative Cover - The general nature of the landscape will exert a significant influence upon the transport of pollutants within the air, water, and land sectors. The channeling of atmospheric pollutants by topographical features such as ridges and valleys is a well known phenomenon. Areas having a greater elevation than the base of a stack will usually be exposed to higher pollutant concentrations than those parallel to the base. Mountainous or hilly terrain may also result in a higher degree of plume depletion due to dry deposition. This is particularly true in heavily forested regions.[6] (Other meteorological phenomena associated with different types of topography will be mentioned in the treatment of climatological effects.)

Topographical characteristics of watershed systems will play a significant role in any water pollution assessment. In this connection some of the parameters of interest are the slope and geometrical cross section of the stream channel and the slope of the land immediately adjacent to the stream. These factors, in combination with other hydrological parameters to be discussed later, can be used to estimate stream flow rates of different rain storm events. The dilution factor associated with a given stream will be directly related to these flow rates. The slope of the terrain near a stream or lake will strongly influence the degree to which erosion will add suspended matter to the water.[7] This factor will be of prime importance in an assessment of environmental effects associated with surface mining. In the discussion of topographical effects in water pollution a watershed system is used as an example. However, a comprehensive analysis must include methods for treating other features such as dams, lakes, estuaries, and bays. For these systems, information should be obtained concerning circulation patterns, tides, and thermal and density stratification.

The type and degree of vegetative cover has implications for pollutant transport in the air, land, and water sectors. In addition to the important role played by vegetative cover in the transport of material pollutants, vegetative cover also has a significant effect upon the adsorption of noise and the stabilization of topsoil.[8,9] The primary influences of vegetation on atmospheric dispersion are its effect upon the wind profile and its tendency to increase the dry depositon rate for most airborne substances. Material deposited on foliage will eventually find its way to the forest floor where it may remain for an extended period of time. Under the action of precipitation, this deposited material may eventually work its way down to the soil and groundwater, but the degree to which this occurs will be a strong function of the chemistry of the substance involved.[10] Vegetation acts as an obstacle to the transfer of incoming precipitation and associated pollution to the ground and stream water. Some of the incident rainfall is trapped by the vegetation and returned to the atmosphere by evaporation.[11] Further moisture loss from the soil can occur through the process of evapotranspiration. Except for the periods of heaviest rainfall, the presence of vegetative cover will prevent the overland flow of moisture and pollutants in a lateral direction. Lateral transport of pollutants is significant for regions with a large amount of impervious area such as rock outcroppings or street pavement (in urban areas).

Climatology - The effect of climatological variables on pollutant transport has been briefly mentioned in connection with the role of rainfall in stream flow, erosion, and pollutant deposition. Although the most obvious use of climatological variables is in the determination of atmospheric transport, these factors are also important in other environmental sectors. The following is a list of these variables and their application:[12,13,14]

- Wind Speed - used primarily to calculate plume dilution and atmospheric stability. Phenomena sensitive to the wind speed include dry deposition, plume rise, fugitive dust emission, evapotranspiration, and lake circulation. Magnitude of the wind speed increases with altitude according to the stability of the atmosphere. Exceptions to this rule may occur for very rough terrain or under special meteorological conditions such as downslope flow.

- Wind Direction - determines which areas are exposed to elevated concentrations of pollutants. Wind direction can be affected by the local topographical conditions especially during periods of light winds. Wind direction will also show a shift with altitude; the magnitude of the shift will depend upon the atmospheric stability condition.

- Cloud Cover - an important parameter in the determination of atmospheric stability. Increased cloud cover is associated with more stable conditions which in turn lead to a lesser degree of vertical and horizontal plume dispersal.

- Solar Radiation Intensity - will depend upon the local latitude, time of day, and time of year. This parameter is used in conjunction with the cloud cover and wind speed to estimate the atmospheric stability. The radiation intensity may also be used to calculate certain photochemical reaction rates.

- Mixing Depth - the atmospheric boundary layer near the earth's surface in which the turbulent diffusion mechanisms predominate. In response to daytime heating of the land, the depth of this layer may be several kilometers, but will be considerably reduced during the night hours. The top of this layer, marked by a discontinuity in the potential temperature profile, acts as a barrier to the vertical migration of material released within the layer. During clear, dry, calm nights, a temperature inversion may form in which the temperature increases with height up to several hundred feet. A low level inversion may also form under the influence of a sea or lake breeze.

- Temperature - an important parameter in the determination of chemical and biological reaction and exchange rates in the air, water, and land; it also influences the transport of the pollutants. The ambient temperature is employed in the calculation of buoyant plume rise.

- Humidity - used in conjunction with the wind speed and solar radiation intensity to estimate evapotranspiration rates. Also important in secondary particulate formation via atmospheric chemical reactions.

If one is dealing with only the long-term aspects of pollutant transport, it is usually sufficient to use annual or seasonal frequency distributions for these meteorological variables. In some cases, however, it may be necessary to analyze the effect of meteorological variables upon elevated short-term pollutant concentrations. This type of analysis would be appropriate for those pollutants for which short-term concentrations have an adverse impact. Even pollutant transport in a stream is sensitive to short-term meteorological events such as a heavy rainstorm. In terms of air pollution this would mean that an inversion breakup, a lake or sea breeze or a stagnation situation should be studied in much more detail. To illustrate how meteorological effects may result in a short episode of high pollutant concentrations, consider the fumigation process associated with an elevated point source located at the bottom of a valley.[15] Overnight radiational cooling under clear skies and light winds will produce extremely stable atmospheric conditions, which in turn will result in very little vertical dispersion of the plume. After sunrise, heating of the valley floor will cause a breakup of the inversion to proceed from the ground upward to the plume axis. This can result in an elevated concentration of pollutant being brought down to the valley floor, a condition which is likely to persist until the inversion breakup moves well past the location of the plume.

Hydrology - The transport of pollutants through the land and water segments of the environment is directly related to the movement of water itself. Some of the precipitation falling upon a watershed is intercepted by the vegetation and subsequently returned to the atmosphere through evaporation. The remainder of the precipitation which reaches the land surface either reaches the stream after falling upon impervious areas or infiltrates below the ground surface. During a storm some of this infiltrated water can reach the stream by migration through the topmost layer of soil. The rest percolates through the unsaturated region of the soil eventually reaching the water table. The ground water found beneath the water table may be separated into active and inactive components. The active ground water is responsible for base stream flow during dry conditions while inactive ground water represents the amount of water diverted from or gained by the watershed as a result of deep seepage. Consumptive water loss due to transpiration from plant surfaces may occur from all soil compartments except for inactive ground water. The partition of water to these various compartments will depend upon soil conductivity and previous moisture content. Once the water finally arrives at the stream channel, its flow rate will be governed by the geometry of the stream cross section, longitudinal slope, and the roughness of the bottom and sides of the stream bed.

Chemical and Biological Characteristics - In addition to a thorough understanding of the climatology and hydrology of an area, a knowledge of the chemical and biological exchange mechanisms specific to the pollutant under study are necessary in the analysis of pollutant transport.

Once a pollutant is deposited on the ground, its future transport through the various soil layers will depend upon its chemical properties. In some cases a substance may be bound so tightly to the upper layer of soil particles that the only means by which it can arrive at the stream is through erosion during heavy rainfall. Pollutants residing in the top layer of soil are also subject to biological transformation under the action of oxidizing or reducing microorganisms. For example, the transformation of elemental mercury to the more biologically toxic substance methyl mercury occurs primarily from the action of soil bacteria. Actual physical pollutant transport in the vertical direction can occur through the action of other organisms, such as earthworms. The depth that a pollutant reaches in the soil is a function of the exchange distribution coefficient, which is a ratio of the equilibrium ion concentration per unit mass of soil to the equilibrium ion concentration per unit volume of water. The value of the distribution coefficient will depend upon the mineral composition of the soil, chemical properties of the pollutant, and the pH of the water. For some substances a soil particle surface is likely to exhibit a highly specific chemical attraction far above what would be expected, based solely upon the basic electrostatic attraction. The calculation of the concentration profile in the soil is usually carried out by specifying a number of soil exchange plates within which equilibrium concentrations exist between the soil particle and in the water phase. Plate concentrations are recalculated after each new volume of water passes through the plate.

After the pollutant enters a stream or lake, either from the land surface or by direct emission, it is still subject to chemical and biological exchange mechanisms. Chemical exchange may take place with either suspended or bottom sediments. In addition to the equilibrium distribution coefficient mentioned earlier, it is necessary to know a rate constant for the exchange process, both for sediments and vegetation present in the body of water. (A number of models which incorporate these chemical and biological characteristics are discussed in Appendix B.)

A wide range of parameters is required to provide a quantitative description of the processes just mentioned. These parameters are usually tailored for input into one or more hydrological simulation models. While the treatment of each of these quantities is beyond the scope of this present discussion, a description of models and associated input variables may be found in a number of texts devoted to the subject of watershed hydrology.[16,17,18,19]

Clearly, these parametric representations of watershed hydrological processes are not adequate for the treatment of special hydrological characteristics, such as conduit transport in karstic areas or sediment transport in arid regions due to flash floods. To adequately deal with these special conditions, the hydrologic models could be suitably modified or special techniques employed based upon studies of the area in question.

Modeling Techniques

The models which could be employed in environmental assessment fall into two general categories: (1) compartmental models, and (2) dispersion models. Both are discussed below.

Compartmental Models - A compartmental modeling approach may be applied when the variables of interest are considered to be uniform within a given region or volume. This technique has been applied extensively in the analysis of constituent transport between different ecosystem components. An example of one such compartmental system is illustrated in Figure 15 where we have schematically indicated the transfer rate coefficients ($a_{i,j}$) between the three compartments and the decay coefficients ($a_{i,i}$) associated with each. The time rate of change of concentration for each compartment is then described by the following expression:

$$\frac{dC_i}{dt} = S_i + \sum_{j=1}^{3} (a_{i,j} C_j - a_{j,i} C_i) - a_{i,i} C_i \qquad (1)$$

where C_i = concentration associated with compartment i

S_i = source strength for compartment i

$a_{i,j}$ = rate constants

$a_{i,i}$ = decay constants.

Once the initial concentrations and source terms have been specified, values for C_i may be calculated using matrix methods. Unless used in conjunction with other techniques, this modeling procedure is only useful for gross estimates of the pollutant accumulated in specific sectors, or for transfer between various sectors. Its primary limitation is its failure to account for areawide transport processes. The user should decide if the simple approach is adequate for his purposes. If compartmental methods are inadequate, dispersion modeling must be used to predict the sphere of environmental influence of a source.

Dispersion Models - The principles of dispersion models are quite similar whether they are designed for an air, water, or land system. Within the model, the transport process may be characterized by terms dealing with

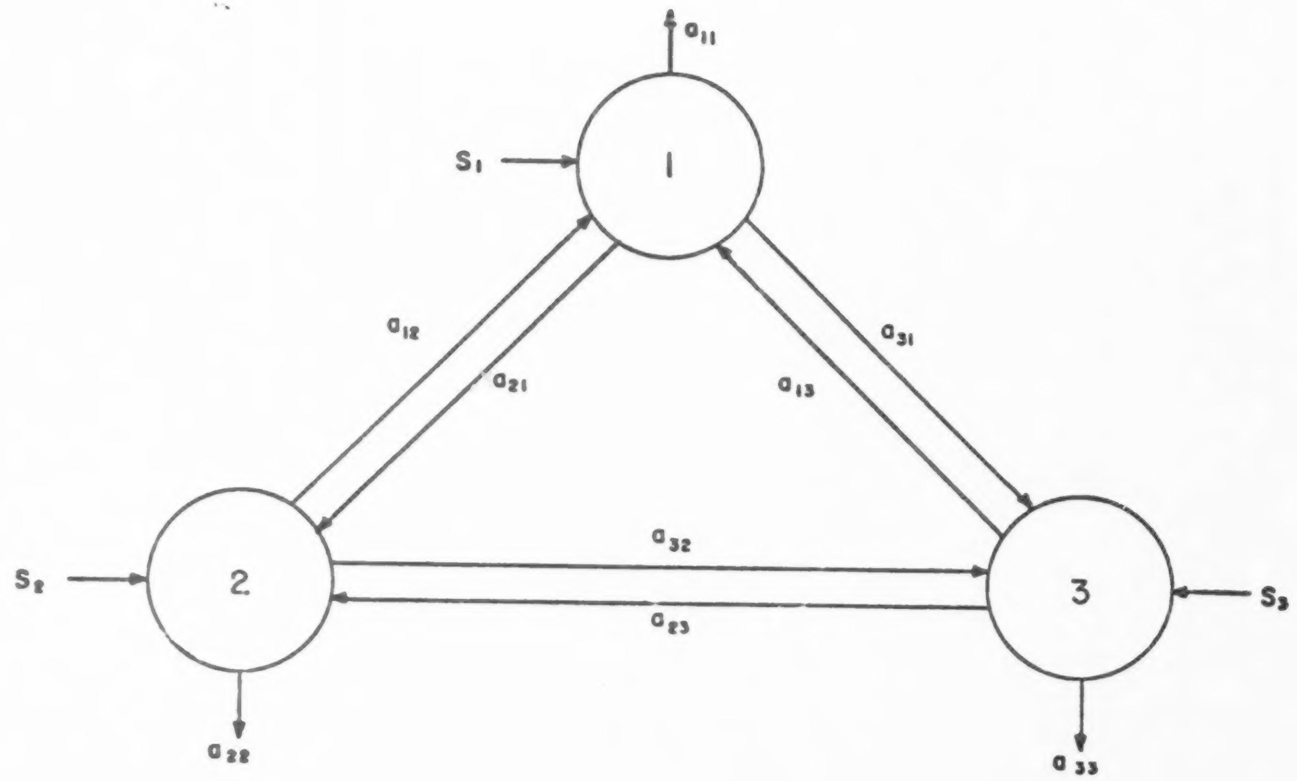


Figure 15. Material balance within a three-component compartmental model

pollutant emission, advection, diffusion, transformation, and depletion. This description may be illustrated by means of a material balance equation for transport in one dimension:

$$\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial x^2} - U \frac{\partial C}{\partial x} - \alpha C + S(x,t) \qquad (2)$$

where C = pollutant concentration

D = diffusion constant

U = velocity of the medium (air or water)

α = depletion rate constant

$S(x,t)$ = source term.

The transport relationship expressed in Equation (2) may be applied with a variety of boundary conditions corresponding to a number of different physical systems (stream, airshed, or soil-water column). The depletion parameters, α, given in Equation (2) will have a different physical meaning depending upon the type of application. For instance, in the calculation of atmospheric transport, α may describe the processes of dry deposition or washout, while in the analysis of aqueous transport, it may be related to pollutant adsorption by vegetation or bottom sediments. The solution of Equation (2) may be developed for either steady state or time dependent mode. In many cases a simple analytic solution to the transport equation is all that is required to estimate the degree and extent of the environmental impact. For applications involving complex boundary conditions, variations in model parameters, or special chemical kinetics, the transport equation must be solved numerically.

After a decision is made concerning which modeling techniques are to be employed, it is important to insure that the data collected are compatible with the requirements of the selected dispersion models. Some input parameters, such as temperature and rainfall rate, are used in pollutant transport calculations for all sectors of the environment. If, during the course of the site-data collection, it is found that some portion of the model input parameters cannot be obtained with the desired accuracy or resolution, the investigator should consider the application of a less sophisticated model. This avoids the needless expenditure of resources in the implementation of large computer programs that will produce results which are no more reliable than the results of simple calculations carried out with the aid of a desk calculator.

A detailed discussion of pollutant dispersion models, including examples of their application in different sectors of the environment, is presented in Appendix B.

The final product of the modeling exercise will be a determination of the ambient concentration and the long-distance range of a given pollutant within each sector of the environment. This assessment should be carried out for a variety of ambient concentration averaging times and emission scenarios ranging from routine operation to an accident situation. The utility of modeling arises because one does not necessarily need a specific site to perform the activities just outlined, but could use an assumed site and still provide a realistic assessment.

REFERENCES

1. Briggs, G. A. Plume Rise. U.S. Atomic Energy Commission Report Number TID-25075. 1969.

2. Cooling Tower Environment-1974. Proceedings of a Symposium Held at the University of Maryland Adult Education Center. March 4-6, 1974. NTIS Number CONF-740302.

3. Halitsky, J. Gas Diffusion Near Buildings. Chapter 5-5 In: Meteorology and Atomic Energy 1968, Slade, D. (ed.). U.S. Atomic Energy Commission Report Number TID-24190. 1968.

4. Shirazi, M. A. and L. R. Davis. Workbook of Thermal Plume Prediction. Volume 2, Surface Discharge. U.S. Environmental Protection Agency Publication Number EPA-R2-72-0056. May 1974.

5. Compilation of Air Pollutant Emission Factors. Second Edition. U.S. Environmental Protection Agency Publication Number AP-42. April 1973.

6. Hosker, R. P., Jr. Estimates of Dry Deposition and Plume Depletion Over Forests and Grasslands. Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, Tennessee 37830. Contribution File No. 85. November 1973.

7. Huff, D. C. and P. Kruger. Simulation of the Hydrologic Transport of Radioactive Aerosols. Advances in Chemistry Series 93. American Chemical Society (1970).

8. Chepil, W. S. Equilibrium of Soil Grains at the Threshold of Movement by Wind. Soil Sci Soc Am Proc. Vol. 23, No. 6, November-December 1959. p. 422-428.

9. Gillette, D. A., I. H. Blifford, Jr., and C. R. Fenster. Measurements of Aerosol Size Distributions and Vertical Fluxes of Aerosols on Land Subject to Wind Erosion. J Appl Meteorol. Vol. 11, 1972. p. 977.

10. Dutt, G. R., M. J. Shaffer, and W. F. Moore. Computer Simulation Model of Dynamic Bio-Physiochemical Processes in Soils. University of Arizona, Tucson. Technical Bulletin 196. October 1972.

11. Murphy, C. E., Jr. and K. R. Knoerr. Modeling the Energy Balance Processes of Natural Ecosystems. Duke University. For: Eastern Deciduous Forest Biome - International Biological Program. Report Number 7240. November 1972.

12. Gifford, F. A., Jr. An Outline of Theories of Diffusion in the Lower Layers of the Atmosphere. Chapter 3, Meteorology and Atomic Energy 1968, Slade, D. (ed.). U.S. Atomic Energy Commission Report Number TID-24190. 1968.

13. Turner, D. B. Workbook of Atmospheric Dispersion Estimates. Public Health Service Publication Number 999-AP-26. U.S. Department of Health, Education and Welfare, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration, Cincinnati, Ohio. Revised, 1969.

14. Holzworth, G. C. Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States. Office of Air Programs Publication Number AP-101. U.S. Environmental Protection Agency. 1972.

15. Carpenter, S. B., T. L. Montgomery, J. M. Leavitt, W. C. Colbaugh, and F. W. Thomas. Principal Plume Dispersion Models: TVA Power Plants. J Air Pollut Control Assoc. Vol. 21, No. 8, August 1971.

16. Crawford, N. H. and R. K. Linsley. Digital Simulation in Hydrology: Stanford Watershed Model IV. Stanford University Technical Report Number 39. 1966.

17. Kazmann, R. G. Modern Hydrology. New York, Harper and Row, 1965.

18. Linsley, R. K., Jr., M. A. Kohler, and L. H. Paulhus. Hydrology for Engineers. McGraw-Hill Book Company, 1958.

19. Veihmeyer, F. J. Evapotranspiration. In: Handbook of Applied Hydrology, Chow, V. T. (ed.). New York, McGraw-Hill Book Company, 1964.

SECTION VI

ASSESSING THE ENVIRONMENTAL IMPACTS OF ENERGY SYSTEMS

INTRODUCTION

In the preceding sections the source has been defined, techniques for quantifying effluents have been discussed, and methodologies for determining indirect pollutant sources and evaluating the sphere of influence of the energy system have been presented. This section presents a methodology for evaluating the interaction of the source with the environment. This methodology includes evaluation criteria which can be used to identify impacts, and provides feedback loops for the modification of the goals of the assessment or of the process itself.

The approach used in this section closely parallels that used in Reference 1. A number of other methodologies for evaluating environmental impacts have been recently reviewed and may also prove helpful.[2] In addition, guidelines for formally preparing environmental impact assessments for selected new industrial sources have been recently prepared and should be consulted.[3]

The information presented in this section can be applied to all stages of system development. In this way, maximum use of the environmental assessment as a planning tool can be achieved.

When determining environmental effects, equal emphasis must be placed on long-term effects as well as on effects which are immediately apparent.

Therefore, it is necessary to project possible environmental impacts of an energy system over a period at least as long as the useful life of the system (generally considered to be 10 or 15 years).

METHODOLOGY FOR EVALUATING ENVIRONMENTAL IMPACTS

There is no universal methodology for evaluating environmental impacts. In all cases, one must ultimately rely on value judgments, which are difficult to quantify and can vary on a case-to-case basis. Any value judgments or assumptions used in evaluating an impact must be explicitly stated; the usefulness of the assessment methodology can then be judged on the basis of its:

- Accuracy - Ability to portray comprehensively and fairly all impacts
- Replicability - Ability to be used by different investigators of the same subject with equivalent results
- Economy - Reasonableness of demands upon the analyzer for time and for sophisticated computational techniques
- Understandability - Ability to be understood by persons of different backgrounds.

The flow chart in Figure 16 outlines a methodology in which evaluative criteria are employed to judge environmental impacts. These judgments provide feedback to the assessment indicating where system modifications must be made or where further information may be required.

The first two steps in the methodology, namely, the evaluation of process emissions and the evaluation of indirect pollution effects, are the end products of previous tasks in the overall environmental assessment process (Sections III and IV, respectively). In the next step — analysis of measures for control or reduction — methods of reducing

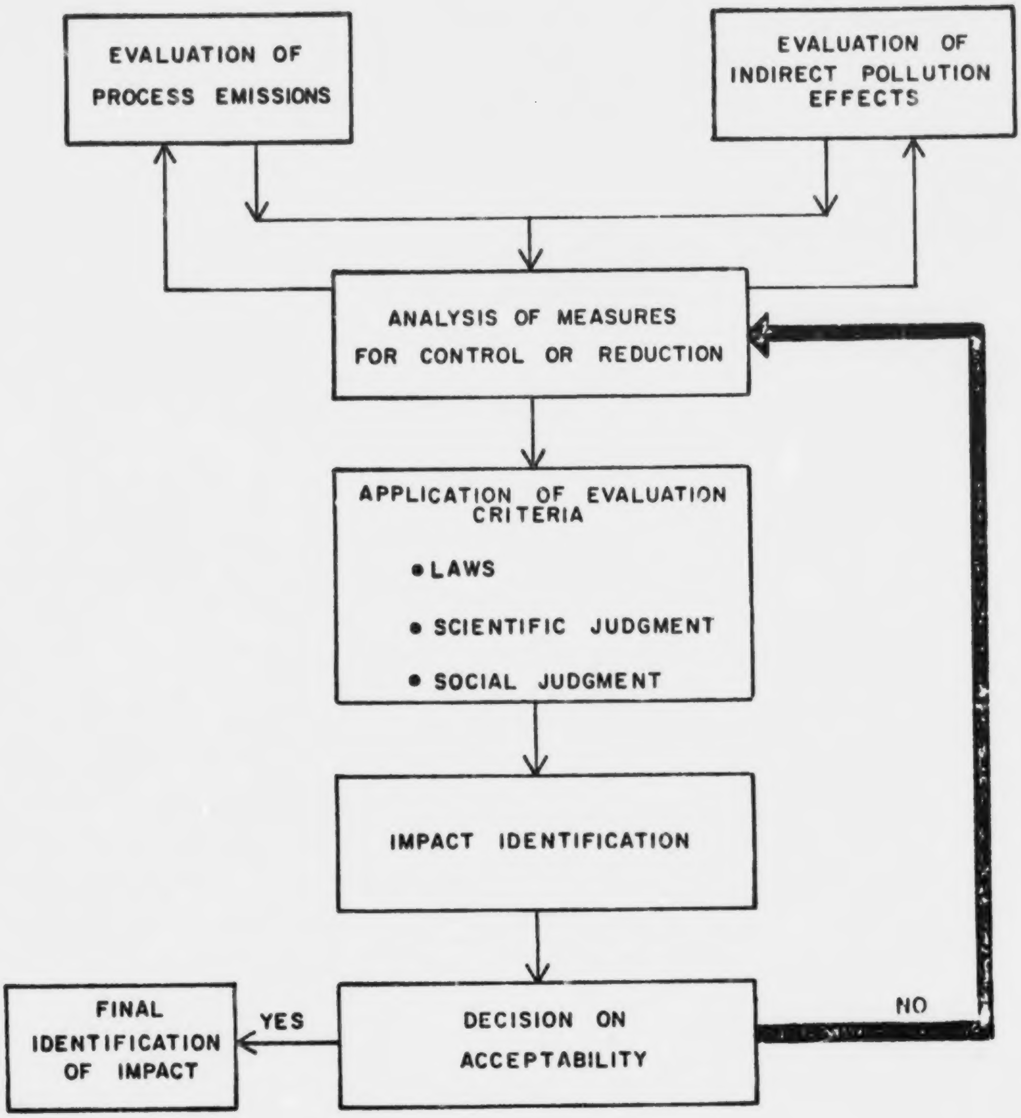

EVALUATION OF PROCESS EMISSIONS
EVALUATION OF INDIRECT POLLUTION EFFECTS
ANALYSIS OF MEASURES FOR CONTROL OR REDUCTION
APPLICATION OF EVALUATION CRITERIA
• LAWS
• SCIENTIFIC JUDGMENT
• SOCIAL JUDGMENT
IMPACT IDENTIFICATION
DECISION ON ACCEPTABILITY
NO
YES
FINAL IDENTIFICATION OF IMPACT

Figure 16. Flow diagram for decisions based on environmental assessments

potentially harmful emissions and/or environmental degradation must be considered. These can range from add-on control technology to extensive modifications of process operating procedures. The possible effects of the emissions must then be evaluated using appropriate criteria. Based on these evaluations, impacts are identified and decisions on acceptability can be made.

The impact assessment methodology, in some cases, can best be performed in two phases as described below.

Phase I Evaluation

The first pass through the steps outlined in Figure 16 could be used to identify all potential pollutant impacts and to determine any additional data requirements necessary for their evaluation. An additional goal of Phase I, however, is the immediate recognition of legal requirements and the determination of the information necessary to insure compliance of the system with the laws.

The information generated in Phase I is basic to the assessment because it provides the first overview of the environmental acceptability of the system. Phase I analysis will play a major role in initial decisions concerning site and technological alternatives.

Phase II Evaluation

In Phase II any required ambient data is collected and data gaps in the process summaries (identified in Phase I) are filled. Phase II analysis can range from literature searches, to analyses of 'worst case' emissions (for systems in the early stages of development), to ambient and source tests of emissions from commercial facilities. Table 3 illustrates the breadth of data which may be needed for a complete Phase II analysis.

Table 3. PRINCIPAL ENVIRONMENTAL ASSESSMENT ANALYSIS FACTORS TO BE CONSIDERED IN THE IMPACT EVALUATION OF A POLLUTANT SOURCE

- **Properties of Energy System Pollutants**
  - Concentration in ambient atmosphere
  - Chemical composition of pollutants
  - Physical state of pollutants
    - Gases
    - Aerosols (liquid or solid)
    - Solid or liquid
    - Physical energy (heat, noise)
  - Sources and/or formation mechanisms
  - Rate of transfer to receptor domain
  - Persistence and sinks
  - Pollutant mobility and movement

- Analysis of Pollutant Behavior in the Environment
  - Environmental media characterization
    - Meteorology and climatology
    - Hydrology
    - Geology and geochemistry
    - Topography
    - Intermedia cycles and interactions

- Exposure Parameters
  - Concentration
  - Duration
  - Concomitant conditions
    - Temperature
    - Pressure
    - Humidity

- Characteristics of Receptors
  - Characterization of receptor population (human, flora, fauna, materials, property)
  - Physical characteristics (spatial distribution)
  - Individual susceptibility
  - State of health
  - Rate and site of transfer to receptor

- Receptor Responses
  - Effects on health (diagnosable effects, latent effects, and effects predisposing the organism to disease)
    - Human health
    - Animal health
    - Plant health
  - Effects on human comfort, satisfaction
  - Soiling and other objectionable surface deposition
  - Corrosion and deterioration of materials
  - Effects on atmospheric properties
  - Effects on radiation properties
  - Ecological system influences
    - Species extinction

Much information required in Phase II can be gathered from data compilations (Appendix C) and previous environmental assessments or impact statements.

The flow chart in Figure 16 is constructed in such a way that evaluations and decisions, based on information generated in previous tasks in the environmental assessment, are considered first. More complex evaluations and decisions can be made after existing data gaps are filled.

As shown in Figure 16, feedback loops should result in generating only necessary data. This should keep the assessment procedures from ballooning to unmanageable proportions; it also insures that the data requirements of each judgment are recognized.

ANALYSIS OF MEASURES FOR CONTROL OR REDUCTION

Control measures can range from application of specific control technology systems to process modifications to changes in raw material requirements. Other options for reducing the impact of emissions could include selection of alternate sites, restricted operation schedules, etc. In analyzing control measures, it is essential to consider the tradeoffs which could be involved in transferring pollutants from one media to another. For example, removal of toxic metals from various process water streams can create concentrated sludges requiring special disposal operations.

Because there are feedback loops in the methodology, the simplest control measures, including the impact of no control, should be considered first. More complicated measures can be analyzed as needed.

EVALUATION CRITERIA

To evaluate the impacts of an energy system on the environment, criteria are needed to determine which pollutants and what concentration levels may be considered harmful or undesirable. Criteria are also required to evaluate the impacts of the resources consumed by the operation of the system; e.g., land use, water use, raw materials extraction. These criteria fall into one of three general categories:

- Legal requirements
- Judgment of scientific experts
- Social values (i.e., public acceptability of the effects of an energy system).

The first priority in assessing the impact of an energy system is to insure that any existing or proposed environmental legal requirements can be met. Obviously, a system which cannot meet these requirements has little chance of successful development. Legal requirements are the most stringent of the above criteria and usually involve the least subjective analysis.

In some cases, legal requirements will not exist for certain pollutants, yet a considerable body of knowledge may exist which indicates that significant environmental impact could result from their release. Examples are air emissions of polynuclear aromatic hydrocarbons and trace metals such as cadmium and nickel. To evaluate the impact under these circumstances, one can rely on the judgment of scientific experts. This judgment may be obtained via a collection of separate opinions or via the convocation of a select committee. Although the results could be controversial, the compilation of expert opinions at least provides a benchmark against which decisions can be evaluated.

Although scientific opinion may judge a process environmentally acceptable, social values could ultimately render it unacceptable. Accordingly, in the evaluation process, one must also devise a systematic manner of judging the public acceptability of an energy system. This can be obtained via public hearings, surveys, polls, committee reports, etc.

Each of these evaluation criteria is discussed in more detail below.

Laws

The primary criteria that must be satisfied are the federal, state, and local laws that regulate the flow of pollutants from the system. Compliance with present legal requirements is considered a baseline activity in the environmental assessment of energy systems. Emissions estimates (Section III) should be used initially to judge compliance. If compliance cannot be demonstrated because of lack of data, collection of this data should be considered first priority in the Phase II analysis. Legal requirements (discussed in more depth in Appendix D) can be broken down into two groups:

- Laws regulating pollutant emissions at the source (e.g., new source performance standards). Failure to comply with these regulations will require system modifications (e.g., particulate control devices, SO_2 scrubbers, etc.) or changes in process parameters (e.g., changes in combustion temperature, changes in input feed).
- Laws regulating ambient concentration of pollutants (e.g., ambient air quality standards). Failure to comply with these regulations may require either system or site modification. Determining compliance with ambient standards requires more information on site characteristics than does determining compliance with source standards.

Analyzing additive and synergistic effects requires that the system planner know the background concentration of pollutants at the site. In cases where pollutant emissions cannot be shown to be clearly below ambient standards, complicated pollutant dispersion modeling may be required to demonstrate projected compliance with legal requirements. Each of these steps requires more and more information about the site and the system and greater degrees of computational complexity.

When using laws as evaluative criteria, compliance with promulgated or future laws must always be considered. These are discussed in Appendix D. A system that may presently be economically and technically feasible may become unacceptable if stricter emission standards are enacted.

Scientific Judgments

Scientific judgments are required to evaluate impacts of pollutant emissions that are not regulated by legal requirements. The use of scientific judgments as evaluative criteria provides a less clear cut indicator of system acceptability than does the use of legal requirements. The question that scientific judgment must answer is: Will the pollutants from a system harm the ambient ecology in any significant way? The important point here is that a judgment must be made as to what is significant. A situation such as the threatening of an endangered species or the emission of known carcinogens could be accepted as a significant impact. A complete analysis of the impacts of an energy system would require, at a minimum, a thorough knowledge of the parameters given previously in Table 3.

Scientific judgment of the impact of the pollutants on the environment is based on three quantities: source/receptor relationships; ambient pollutant concentration levels; and exposed receptor populations.

Source/Receptor (S/R) Relationships - S/R relationships express the effect of a particular pollutant concentration level on a specific receptor (animal, plant, etc.) in the environment. S/R relationships are generally reported as a concentration level at which a specified effect occurs (i.e., a threshold limit value, {TLV}), or as a concentration that, if maintained for a specified time period, will prove lethal to a certain portion of a specified receptor population (i.e., a lethal dose for 50 percent of the population, {LD_{50}}). S/R relations are specific to a medium and stand as a body of knowledge independent of the site and the energy system (see references 4 to 8). The particular system determines the pollutants, and the site determines the receptor population and, to some extent, the pollutant medium and concentration level. S/R relationships are the analytical tool which measures the impacts of an energy system. (Data compilations for toxicological properties of pollutants are listed in Appendix C.)

Ambient Concentration Levels - Three dimensions of ambient pollutant concentrations are important for a quantitative impact assessment of pollutants on receptor populations: (1) pollutant concentration, (2) exposure duration, and (3) trend over time. This information is important in quantifying adverse effects where S/R relations are known, and also for characterizing the severity of potential pollutants in terms of their persistence, general emission trends, and potential geographic scales of influence. The response of a receptor is determined for exposures lasting for a specified time. For example, occupational standards are usually determined for an 8-hour exposure period. Generally, environmental standards are expressed as 3-hour, 24-hour, 96-hour, or annual average. Considerable discretion must be used in interpreting the effect of pollutants in the environment when extrapolating source/receptor relationships for exposure over a time period different from that for which they were measured.

Exposed Receptor Population Inventory and Characterization - The third basic parameter for assessing system pollutant effects is a measure of the population of exposed receptors. Receptor populations are defined in a broad context here to mean people, vegetation, animals, materials, and other elements of the physical environment for which effects criteria have been defined. An inventory of receptor populations requires a regional breakdown consistent with relevant pollutant monitoring capabilities, and characterization along categories consistent with toxicity data (e.g., classification of populations by sensitivity groupings - people, plant species, etc.) and energy system site characteristics.

Guidance on receptor population characterization is limited by available data bases to assist such inventories. Even for major receptor categories, such as humans, animals and plants, quantitative measures for impact calculation are incomplete at the present time. Thus, although general guidelines can be presented for performing evaluations based on scientific judgments, the quantification of the impacts of an energy system on the environment requires the use of a multidisciplinary team of expert evaluators. This will insure the proper recognition of problem areas and their correct interpretation.

Generally, the spatial extent over which receptor populations must be considered is limited by the sphere of influence of the source and the minimum concentration level of the pollutant capable of producing an effect.

The use of scientific judgments as evaluative criteria will depend on the goals of the assessment and the depth to which the assessment is completed. A Phase I assessment may just determine if legal requirements can be met. However, for Phase II assessments, the salient features of pollutant impact on the environment must be explored. These will include:

- The long-term effect of pollutants over at least the life of the system
- The ability of pollutants to accumulate in natural sinks
- The effect of pollutants on special receptor groups (e.g., endangered species, migratory species)
- Additive or synergistic interactions of pollutants in the environment
- Climatological features that can alter the sphere of influence (e.g., acid rain).

Literature sources and previous environmental assessments or environmental impact statements for similar systems or sites can prove to be invaluable aids in this part of the assessment and should be consulted. In addition, there are, at present, methodologies for rank ordering pollutants according to their potential for harming the environment.[9-16] These schemes focus attention on pollutant emissions having the greatest potential for harm and are of potential use. However, they do require large amounts of input information, and their use is recommended only for very comprehensive assessments.

Social Criteria

Social criteria, or public acceptability, may determine if the siting of the system will be allowed. Social criteria are also the most difficult to quantify, but should be included in any assessment. They are sometimes the last evaluative judgments to be satisfied, but they are not necessarily the least important. They should be included in any assessment of systems beyond the pilot plant stage of development.

Social criteria have been touched on in Section IV. Some examples are:

- Aesthetics
- Recreational use of waterways
- Noise
- Land use
- Materials and property damage.

In certain cases, social criteria may be the most important criteria. This is true for systems which generate few waste products (e.g., fuel cells or solar power) or for systems for which the effect of accidents, however remote, may be widespread (e.g., nuclear power systems).

IMPACT IDENTIFICATION

The previous evaluation criteria can be applied to several types of impact. Basically, these are included in categories such as those listed below.[3] Using the previous evaluation criteria, priorities can be assigned to each of these impacts. The priorities are usually best assigned by a multidisciplinary team of experts.

- Significance versus Magnitude - Magnitude is measurable by some physical property (e.g., pounds of organic carbon); significance is measured by a subjective weighting factor which indicates the benefit or detriment of the impact

- Inevitable versus Possible Impacts - Inevitable impacts are readily measured (e.g., flow of a river, concentration of Hg); possible impacts may not occur but could be very significant if they do (e.g., an oil spill)

- Cumulative Impacts - The sum of individual impacts must be considered

- Long-Term versus Short-Term Impacts - The persistence of an impact must be evaluated

- Reversability - The extent to which the impact can be nullified by natural processes must be considered.

EXAMPLES OF POSSIBLE DECISIONS

Many federal agencies and divisions within federal agencies are developing guidelines to assist in the decision-making process. Tables 4 and 5 are taken from a recent set of guidelines for environmental impact assessment for selected industries.[3] They are used simply to illustrate some of the decisions one may encounter in an environmental assessment program.

Table 4. EXAMPLES OF PROCESS-RELATED DECISIONS WHICH MAY BE ENCOUNTERED IN AN ENVIRONMENTAL ASSESSMENT[3]

No.	Criteria - Process Related	Option
1	The proposed process is likely to be controversial for environmental or public health reasons.	Consider at least one other process option.
2	Process technology for the industry in question is rapidly developing or expanding.	Consider postponement of the project.
3	Pollution control technology is rapidly expanding for some critical or costly facet of the industry.	Consider postponement of the project.
4	Renovation/expansion of existing facilities would eliminate the need to develop natural areas.	Consider renovation/ expansion.
5	The proposed project will rely upon relatively unproven technology.	Consider at least one other process option.
6	The proposed project utilizes scarce or rapidly diminishing resources (e.g., natural gas).	Consider at least one other process using other resources.
7	The proposed project has several raw materials options.	Consider all raw material options and determine one causing lowest pollution load.

Table 5. EXAMPLES OF SITE-RELATED DECISIONS WHICH MAY BE ENCOUNTERED IN AN ENVIRONMENTAL ASSESSMENT[3]

No.	Criteria - Site Related	Option
1	The proposed new source location is likely to be controversial.	Consider at least one additional site.
2	The proposed new source and/or associated facilities would infringe upon scientifically valuable areas, as determined by site uniqueness, primitiveness, amenability to study or observation. Such sites may be defined by local universities, colleges, research organizations, etc.	Consider at least one additional site.
3	The proposed new source and related facilities would directly or indirectly infringe upon recreational lands, wildlife refuge lands, etc.	Consider at least one additional site.
4	The proposed new source and related facilities would either directly or indirectly accelerate change in rural, pristine, or agricultural land areas.	Consider at least one additional site.
5	The proposed new source and related facilities would induce secondary residential, industrial, and/or commercial growth in the community which could not be supported by existing community services and financial capabilities.	Consider at least one additional site.
6	The proposed new source and related facilities would cause traffic congestion in the vicinity of the proposed site.	Consider at least one additional site.
7	The proposed site is prone to flooding, hurricane, earthquake, or other natural disasters.	Consider at least one additional site.
8	The proposed new source and related facilities would infringe directly or indirectly upon endangered species or their habitat, or upon wetlands, (including fresh-water wetlands), upon wild and scenic rivers, or sensitive or unique ecosystems.	Consider at least one additional site.
9	The proposed new source and related facilities would infringe directly or indirectly upon historical sites currently included or proposed for inclusion within the National Registry of Historical Landmarks. Archaeologically important sites are likewise covered by this criterion.	Consider at least one additional site.

ASSESSING THE ENVIRONMENTAL IMPACT OF SYSTEMS AT DIFFERENT STAGES OF DEVELOPMENT

In terms of the system breakdowns presented in Section II, the following general observations can be made regarding the evaluation of energy system impacts.

Bench Scale or Conceptual Models

There is, in general, no ambient data available for bench scale models as no site is chosen. However, in certain cases, site selection may be constrained by the inherent requirements of the system (e.g., mine mouth or residential use). In these instances, 'worst case' analyses can be used to determine if, even at this early stage of system development, the system will produce any significant impact.

Similarly, data systems such as MERES* (see Appendix C) can be used to predict pollutant loadings by analogies with similar systems. Potential raw material requirements can be calculated and the impact of their extraction determined. It is important, at this stage of system development, to acknowledge the effect on system development of future laws that may be in effect when the system goes on line.

The most important aspect of using the approach shown in Figure 16 on a bench scale system is in determining the information required from the next step of system development — the pilot plant. By recognizing data needs early, the environmental assessment can be used as an efficient data gathering vehicle.

---

*MERES — Matrix of Environmental Residuals of Energy Systems. A compilation of projected source emissions.[5]

Pilot Plant

The major advantage in determining environmental impacts at the pilot plant level is the flexibility which is available at this stage of development. If potential environmental problems are identified, system design or operating parameters can be modified comparatively easily to investigate changes in pollutant loadings. One potential drawback in evaluating environmental impacts at the pilot plant level, however, is that the size of the plant may be much smaller than projected full-scale facilities. Caution should be exercised in extrapolating data from pilot plants which are significantly smaller (e.g., an order of magnitude) than the size of the proposed commercial installations.

Potential environmental impacts, recognized at the pilot plant stage, can be minimized by proper planning and construction in the next stage of system development — the demonstration plant. Demonstration plants are usually at least half the size of the projected full-scale facility. Recognizing data needs will also make planning of the demonstration plant and subsequent ambient monitoring facilities much more efficient.

Demonstration Plant

Determination of the environmental impacts at a demonstration plant will provide three main benefits. First, by identifying data gaps and requirements, it will make ambient data collection efficient. Second, it will determine what pollution control, if any, is required, and to what degree pollution control must be practiced. Finally, as a planning device, it can be used to identify future legal requirements on pollutant emissions and allow adequate lead time for the necessary planning and implementation of control technology.

REFERENCES

1. Energy Alternatives: A Comparative Analysis. Prepared for Council on Environmental Quality by the Science and Public Policy Program, University of Oklahoma, Norman, Oklahoma. U.S. Government Printing Office. Stock Number 041-011-00025-4. May 1975.

2. Warner, M. L. and E. N. Preston. Review of Environmental Impact Assessment Methodologies. Battelle Columbus Laboratories, Columbus, Ohio. Prepared for U.S. Environmental Protection Agency. Publication Number EPA-600/5-74-002. April 1974.

3. Environmental Impact Assessment Guidelines for Selected New Source Industries. Draft Report. Office of Federal Activities, U.S. Environmental Protection Agency, Washington, D.C. August 1975.

4. Kemp, H. T. et al. (literature to 1968). Water Quality Criteria Data Book - Effects of Chemicals on Aquatic Life. Volume III. U.S. Environmental Protection Agency. May 1971. And: Kemp, H. T., R. L. Little, V. L. Holoman, and R. L. Darby (literature 1968-1972). U.S. Environmental Protection Agency. September 1973.

5. Christensen, H. E. and T. T. Luginbyhl (eds.). The Toxic Substances List. 1974 Edition. U.S. Public Health Service, Center for Disease Control, Rockville, Maryland. 1974.

6. Epstein, S. S. Toxicologic and Epidemiologic Bases for Air Quality Criteria. (FR-8 Committee of Air Pollution Control Association, Chairman. 1969.)

7. Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment With Intended Changes for 1974. American Conference of Governmental Industrial Hygienists. Cincinnati, Ohio. Copyright 1974.

8. Schindler, A. and Max Samfield. Estimation of Permissible Concentrations of Pollutants for Continuous Exposure. Part I: Permissible Air Concentrations. Prepared for U.S. Environmental Protection Agency, Environmental Research Center, by Research Triangle Institute, Industrial and Environmental Research Laboratory, under Contract No. 68-02-1325, Task Order No. 34. September 1975.

9. Arthur D. Little, Inc. Final Report Relating to the Present Status and Requirements for Occupational Safety Research. Prepared for the National Institute of Occupational Safety and Health. 1972.

10. Hosey, A. D. Priorities in Developing Criteria for Breathing Air Standards. Journal of Occupational Medicine, 12(2):43-46. February 1970.

11. The President's Report on Occupational Safety and Health. U.S. Department of Health, Education and Welfare, Washington, D.C. U.S. Government Printing Office. December 1973. p. 105-106.

12. Reiquam, H., N. Dee, and P. Choi. Final Report on Development of Cross-Media Evaluation Methodology. Volume II. Battelle Research Laboratories. Report to the Council on Environmental Quality and Environmental Protection Agency. January 15, 1974.

13. Reiquam, H. Establishing Priorities Among Environmental Stresses. Indicators of Environmental Quality. W. A. Thomas (ed.). New York, Plenum Press, 1972. p. 71-82.

14. Norbert, D. et al. Environmental Evaluation System for Water Resource Planning. Battelle Columbus Laboratories, Columbus, Ohio. January 1972.

15. Klee, A. J. Models for the Evaluation of Hazardous Wastes. National Environmental Research Center, U.S. Environmental Protection Agency, Cincinnati, Ohio.

16. Carroll, J. W. Formulation and Assessment of Air Pollutant Abatement Strategies and Priorities, Task 1.0 Air Pollutant Prioritization Methodology. GCA/Technology Division, Bedford, Massachusetts. September 1974.

APPENDIX A

SOURCE AND AMBIENT TESTING AS PART OF AN ENVIRONMENTAL ASSESSMENT PROGRAM

INTRODUCTION

The necessity of sampling and analyzing pollutants both at the source and in the ambient environment was discussed in Sections III and V. Because this report deals with the assessment of systems at all stages of development, sampling and analysis efforts can range from simple grab samples to complete on-line monitoring programs.

A complete description of all sampling and analysis procedures is outside the scope of this document. This appendix mainly addresses sampling strategy, along with a brief description of appropriate analytical considerations. The information presented here is not intended to be complete or exhaustive. Rather, it is presented to give an overview of an extensive field of knowledge that will be of use in the planning and implementation of an environmental assessment.

The discussion is organized into the following general areas:

- Source Tests: Sampling and Analysis
  - Air
    - Federally recommended methods
    - Gases
    - Particulates

Preceding page blank

- Source Tests: Sampling and Analysis (continued)
  - Water
    - Federally recommended methods
    - Dissolved species
    - Suspended solids
    - Organic compounds
  - Solid Waste
    - Waste piles
    - Leachates
    - Fugitive dust and runoff
- Ambient Tests
  - Sampling strategy
  - Analytical requirements
- Quality control in sampling and analysis.

SOURCE TESTS: SAMPLING AND ANALYSIS

Presampling Survey

Source testing programs should be undertaken only after careful and detailed planning to ensure sampling completeness, appropriate scheduling, and maximum efficiency of personnel and hardware.

The information necessary to plan source testing adequately can best be obtained through site visits; i.e., "presurvey" trips. The major functions of the presurvey are to:

- Evaluate specific sampling sites and determine the frequency and method of sample collection
- Determine basic conditions of each stream to be sampled (flow rate, temperature, pressure, major components)
- Arrange for necessary monitoring of process parameters
- Acquire a sample of each major type of process and effluent material for preliminary testing.

Sampling

Introduction - No analytical result, regardless of the accuracy and precision of the procedure, can be any better than the quality of the sample submitted for analysis. The primary tasks involved in source tests on an energy system involve sampling effluent streams such as stack venting systems, cooling towers, or water discharge streams.

The identification of pollutants discussed in Section III and the discussion of data requirements in Section V provide the necessary input for deciding when, where, and what to sample. It is essential that the first steps in any sampling and analysis program are the determination of the compounds of interest and the decision on where in the process stream samples are to be taken. Therefore, it is necessary that the assessment provide at least an initial estimate of the identities and quantities of pollutants generated by the energy system and the phase (i.e., solid, liquid, gas) in which these pollutants are emitted.

The initial sampling objective should be to characterize comprehensively the effluent stream of interest and establish acceptable sample sizes. The "physical" properties of the stream must also be measured (i.e., average velocity, velocity gradients, temperature, pressure, extent of turbulence, etc.). Changes in stream velocity will alter the emission rate. Velocity gradients and turbulence will affect the extent of mixing which in turn can alter the chemistry of the stream.

For processes involving cyclic operating conditions, it may be necessary to sample at the same point during several cycles to accumulate the required amount of sample for analysis. In this vein, the sensitivity of the particular analysis procedures must be known in advance in order to determine the minimum sample size needed. A thorough knowledge of analysis requirements avoids the expenditure of more time and effort than are necessary to achieve the required effluent stream characterization.

Sample collection times must be long enough to collect sufficient quantities for analysis, yet short enough to observe changes in effluent concentrations due to changes in operating conditions. Assessment of a source which has substantial variations with respect to process parameters (for example, the use of an MHD power generator to meet peak load requirements) requires an emissions-weighted average using the frequency of occurrence of the various process combinations. If this proves impractical, a "typical" situation for detailed analysis can be chosen.

Sampling points should be selected as close as possible to the actual ejection port of the stream, so that the sample reflects more closely the emissions from the system. In cases where control devices exist or are planned, samples are taken upstream and downstream from the control device. Samples are not taken near obstructions or bends in the duct since atypical concentration or flow gradients are usually present at such places.

Sampling variations such as traversing or proportional sampling should always be performed at the outset of any testing program to characterize the effluent stream. Once the effluent stream has been well characterized, prudent judgment will determine the degree of sophistication required in subsequent tests. In the simplest case of a stack which has a constant average duct velocity (volume flow rate) and a constant pollutant gas concentration, it is only necessary to sample at one point at a constant sampling rate.

The following subsections provide brief summaries of sampling techniques commonly used for air, water, and solid waste source tests. It is not an exhaustive review of the subject, but is aimed primarily at providing background information and familiarity with current practices. Where appropriate, reference is made to monitoring handbooks or literature reviews.

Air Sampling - Air sampling includes the collection of both gaseous and particulate species. Each will be discussed separately, although in some instances the same considerations or precautions apply to both categories.

Federally recommended air sampling methods - For the six criteria air pollutants* — SO_2, NO_x, suspended particulates, CO, hydrocarbons, and total oxidant (as O_3) — Federal Reference sampling and analytical procedures have been established and updated.[1,2,3,4]

Use of the Federal Reference techniques is not required in all situations; however, they are strongly recommended for compliance testing. If an alternate method is used, the rationale for use should be explained.

Gaseous sampling - Discussing, in any detailed manner, the proper sampling procedures for all possible source types and related gases encountered in an assessment program requires an unwarranted degree of effort. The approach taken here is to describe conventional sampling methods, indicate the advantages and disadvantages of each, and finally, show how they are applied in some specific field applications.

- Grab Sampling - A representative gas sample is collected in a suitable container such as an aluminized bag, a stainless steel vessel, or a glass bulb. A typical example is the EPA Grab Sample Train used for measuring NO_x in stack gases. The sample collector consists of a sealed evacuated flask containing an absorbing solution. Particulate matter is removed by a glass wool filter at the inlet to the flask. When the seal on the flask is broken, the sample fills the bulb which is then stoppered and transported to the laboratory for analysis. A similar technique, using aluminized Scotchpak bags, usually fitted with Roberts valves,[3] has been used for sampling hydrocarbons.

  Convenience and ease of handling are the advantages of grab sampling. A disadvantage of this method is the frequent difficulty in maintaining the extracted sample in the original source condition. For instance, in sampling a high temperature process stream, the sample can cool considerably before it is finally analyzed, thus introducing the possibility of significant error due to condensation.

---

*As designated in the Clean Air Act of 1970 (see Appendix D).

Grab sampling is never suitable for analyzing reactive gas mixtures such as Cl_2 and NH_3 which react rapidly to form solid NH_4Cl. Grab sampling may also reduce the selectivity of analytical techniques. For example, sulfuric acid mist is sometimes measured by collecting the sample on a suitable filter media for subsequent analysis by flame photometry. With this mode of sampling, solid sulfate salts are also collected, leading to erroneously high estimates for sulfuric acid concentrations. In grab sampling, the pollutants are not preconcentrated.

- Integrated Flow Sampling - In integrated flow sampling, a continuous flow of sample is pulled through the sampling train. In the sampling train the sample is bubbled through special solutions. The component of interest can either be selectively dissolved or precipitated out of solution. The sampling train consists of gas meters, pumps, filters, absorption columns, etc. A typical example is the EPA Absorption Train for determining sulfur dioxide in stack gases. A pump draws the gas sample through the system and a filter is used to remove particulate matter prior to gas scrubbing with the absorbing solution. The scrubbing solution is then analyzed for SO_2. One of the major difficulties of this type of sampling is incomplete absorption of the gaseous species. Interfering factors can also result from changes in pH caused by the solvation of other gases and from turbidity caused by precipitate formation.

- In-Situ Analysis - Recently developed in-situ measuring techniques involve no sample extraction. An example is the Correlation Spectrometer[5] in which an ultraviolet light beam is projected into a stack and then reflected back to a sensor. The absorption spectrum of the light beam is then compared with standard spectra to determine concentrations of species of interest. The technique is presently applicable to NO, NH_3, SO_2, and halogens and shows considerable promise for other materials. Another type of in-situ monitoring is the remote sensing of either ambient or plume concentration levels by Lidar Spectroscopy.[6]

The following general precautions are necessary to provide proper sampling of gaseous species:

- Proper Construction Materials - The sampling system must be constructed from materials that will not react with the species of interest, nor provide sites for selective adsorption of these species.

- Temperature - The temperature drop during transport from the sampled environment, such as a stack, to an analytical instrument must not be so large as to cause condensation, increased wall adsorption, or shifts in equilibrium concentrations.

- Prefiltering for Particulate Matter - When sampling for trace gaseous substances it is often desirable to prefilter the gas to remove particulate matter. There are two reasons why prefiltering may be necessary: (1) the particulate matter itself may contain substances which will react with the chemicals used for analysis and (2) the particulate matter may form blockages in the collection equipment, especially those using small critical orifices for gas metering, which will contribute to errors in the volume measurement of gases sampled.

- Adsorption Effects - When handling trace concentrations of gases, it should always be recognized that adsorption onto sampling containers or lines can cause significant error. For example, nitrogen oxides are adsorbed very strongly on to glass surfaces, requiring the rinsing of glass used in the sampling train with Saltzman's reagent to obtain precise results.

- Diffusion Losses - The use of plastic containers for storage of gaseous samples may result in substantial errors in apparent sample concentrations due to selective diffusion losses through the plastic. Thus, the interval between collection and analysis should be kept at a minimum. Similarly, plastic tubing used for sampling or analysis equipment should be as short as possible.

- Mechanical Defects - Leaks are the most common source of error in ambient and source sampling. Leaks often occur at seals and valves and are not always readily detectable by simple visual inspection of equipment.

Particulate sampling - Particulate sampling presents unique sampling problems because particles are often distributed nonuniformly at pipe bends or obstructions. In particle sampling, the gas from the effluent stream is drawn through a probe and the particles are deposited on a suitable substrate such as a filter or a sticky surface. The best results are usually obtained when the flow velocity into the probe is the same as that in the stack (referred to as 'isokinetic' sampling). Because of the mass gradients mentioned above, traversing probes are often used with isokinetic sampling conditions.

Common problems in particle sampling are losses via agglomeration (especially important in particle size measurements), losses by deposition on surfaces, and losses via electrostatic interactions with walls or protrusions. Not only are losses encountered when sampling for particulate, but positive errors may result from extraneous contributions due to absorbed water or other vapors, or the formation of particulates from catalytic reactions on the surfaces of particle collectors.[7]

Water Sampling - Water is sampled for dissolved substances, organic compounds, inorganic compounds, suspended solids, pH, temperature, etc. In water sampling, grab samples, integrated flow-sampling, or in-situ analysis can be used. Monitoring performed at the outfall, the point where the effluent stream from the facility meets the receiving water segment, can be used to determine total plant effluents. In addition, each tributary to the overall waste system should be sampled to determine when and where pollutants originate. To determine the source of pollutants, a complete path of the plant's drainage system should be mapped, keeping in mind that wastewater effects are not necessarily limited to physically connected waterways. For example, leachates from solid waste disposal sites can contaminate underground water streams. (Leaching will be discussed further in the section on solid waste disposal.)

Federally recommended methods - A sample of the types of recommended procedures for sample preservation and sample holding time, taken from EPA's Methods for Chemical Analysis of Water and Wastes,[8] is shown in Table 6.

Table 6. A SELECTION FROM EPA'S RECOMMENDED PROCEDURES FOR SAMPLING AND PRESERVATION OF WATER SAMPLES[8]

Measurement	Volume required, ml	Container	Preservative	Holding time
Acidity	100	P,G	Cool, 4°C	24 hours
Alkalinity	100	P,G	Cool, 4°C	24 hours
Metals				
Dissolved	200	P,G	Filter on site HNO_3 to pH 2	6 months
Suspended			Filter on site	6 months
Total	100		HNO_3 to pH 2	6 months
Organic carbon	25	P,G	Cool, 4°C H_2SO_4 to pH 2	24 hours
Organic compounds	min 1000	Gw/Teflon liners	Refrigerate	Extract ASAP
pH	25	P,G	Cool, 4°C Determined on site	6 hours

These procedures are not mandatory, but they have been developed as a result of wide experience in the field of wastewater sampling. A supporting rationale should be supplied if alternative techniques are used.

Sampling dissolved species - In-situ analysis by ion-specific electrodes is often used to great advantage in monitoring dissolved species. If grab samples or sequential sampling techniques are used, the selection of a glass or plastic sample container is determined by the potential for leaching of ions to or from the container. Because significant quantities of soluble species such as metals can be contained in suspended solids, reported concentrations for these species determined from analysis of soluble components must be considered lower limits.

Sample preservation techniques using chemical additives "fix" the species of interest in a stable form in solution. Cooling of samples to 4°C is also generally recommended to maintain sample quality. Again, however, the secondary effects of temperature change and the presence of preservative must be taken into account when processing samples. For instance, an acid preservative cannot be used on a sample which will be tested for pH, nor can a $HgCl_2$ preservative be used on a sample to be tested for mercury content or total chloride. Table 7 lists some commonly used preservatives and their function with respect to "fixing" soluble species. The importance of preservation has been demonstrated by a study of Hg losses from creek water during storage. Losses ranged as high as 60 percent for a water sample without added preservatives after only minutes of storage in a polyethylene bottle.[8]

Sampling suspended solids - In some cases, in-situ analysis can be made on suspended solids via light scattering techniques; however, because bubbles and turbulence will cause interference, grab samples are generally

Table 7. PRESERVATIVES FOR WATER SAMPLES[8]

Preservative	Action	Applicable to
$HgCl_2$	Bacterial inhibitor	Nitrogen forms
Acid (HNO_3)	Metals solvent, prevents precipitation	Metals
Acid (H_2SO_4)	Bacterial inhibitor	Organic samples (COD, oil and grease, organic carbon)
	Salt formation with organic bases	Ammonia, amines
Alkali (NaOH)	Salt formation with volatile compounds	Cyanides, organic acids
Refrigeration	Bacterial inhibitor	Acidity-alkalinity, organic materials, BOD, color, odor, organic P, organic N, carbon, etc., biological organism (coliform, etc.)

preferred. If only turbidity measurements are important, light scattering techniques will usually suffice. If chemical analysis of the suspended solids is required, the solids can be separated by filtration, centrifugation or evaporation and then be separately analyzed. If evaporation is used, care should be exercised to insure that the solids themselves are not volatile and hence subject to loss during evaporation.

Sampling and preparation of organic compounds - To prevent reactions between organic compounds and other water stream contaminants, organics should be extracted from the water effluent stream during or immediately after sampling. Chloroform is suggested as the most suitable extracting solvent,[9] particularly for those compounds to be analyzed by gas chromatography-mass spectrometry. After extraction, samples should be frozen until analysis.

Water sampling precautions - Unique problems encountered in water sampling are:

- Dissolved Gases and Temperature Effects - In sampling, special care must be given to tests for dissolved gases. Changes in temperature of the sample can rapidly and drastically alter pH and concentrations of dissolved gas. This, in turn, may cause some chemicals to precipitate, thus causing a change in total hardness, salinity, etc. Therefore, monitoring of variables such as pH, temperature, and concentration of dissolved gases should always be performed in the field.

- Extraneous Sources - Source tests may or may not be influenced by extraneous pollution sources, depending on the construction of the effluent disposal system. For instance, if the storm sewers of a plant and the waste water from a boiler blowdown operation drain to the same effluent stream, then sampling the stream after the junction point would measure the cumulative effect of blowdown and runoff.

Solid Waste Sampling - Solid waste sampling may be divided into three general areas: the pile itself, leachates, and fugitive dust and run-off. Solid wastes can originate in many sections of an energy facility (e.g., ash from boilers, particulates from settling ponds, etc.); they are almost always disposed of as landfill.

Waste piles - The most reliable results for waste pile analysis are derived from a systematic grid approach to sampling.[10] Because the composition of solid waste piles changes very slowly, these piles need only be sampled on a monthly or even less frequent basis. However, solid waste piles should be sampled whenever their composition may suddenly change (e.g., an ash pile should be sampled whenever the composition of the process coal changes radically).

Solid samples are usually taken from piles with the use of an auger or borer. In this fashion, cumulative or stratified sample sections can be attained. Samples are prepared for analysis by drying, grinding or pulverizing, and mixing. The end product should be so homogenized that even a small sample (100-200 mg) can be accurately considered representative of the entire sample.[11]

Leachates - Leachates are defined as the liquid produced when water passes through solid waste and flushes out decomposition products. Leachates should be sampled in subsurface strata and in any underground or surface water segment out to those distances from the source at which background concentrations are reached.[11]

It is very difficult to project when to sample leachates since they travel slowly and unpredictably. Typical leachate migration rates can range from 0.5 to 30 m/year.[11] Soil column experiments give, at best, an accuracy of ± 1 year in terms of the migration rate when compared with field tests.

In addition, leaching rates can vary with time. Therefore, leachates should be tested often enough to insure that any erratic behavior or rapid rise in leaching rate is detected.

In new facilities, sludges and solid wastes are stored on impervious liners. These liners are designed to prevent leachates from entering the soil. However, the surrounding soil should occasionally be tested for any leachates which might escape through rips in the liner, runoff, or disposal pond overflow. Recent work on the use of these liners is summarized in reference 12.

Leachates are collected by using wells or piezometers placed in drilled holes. A piezometer consists of a small section of pipe covered at one end by a wire screen and connected to the end of a long rod. The rod is placed in a boring, and the water obtained in the pipe sections is representative of the leachate at the bottom of the boring. By adjusting the length of the open section of pipe, samples representative of large vertical distances of soil can be obtained. Pore water samples above the groundwater table are taken with suction lysiometers. Leachate samples should be cleared of suspended solids by sedimentation and not filtration, as the latter may remove significant amounts of heavy metals and phosphates.

Most leachates are formed under anaerobic conditions and will suffer significant sample deterioration when exposed to the air. Therefore, leachate samples should be placed in stoppered bottles and analyzed immediately. Suspended solids, turbidity, dissolved oxygen, and pH readings are dependent on the time between collection and analysis.

After collection, leachates are treated in the same manner as water samples. The main parameters of interest are summarized in Table 8.[13]

Table 8. PRIMARY AND SECONDARY LEACHATE PARAMETERS TO BE MEASURED[13]

Primary		Secondary	
Parameter	Reason for measurement	Parameter	Reason for measurement
Conductivity	Function of salts and volatile free fatty acid concentration	COD (Chemical Oxygen Demand)	Concentration of organics
Absorbance at 400 μm	Iron and other inorganic concentrations	TS (Total Solids)	Presence of organics and inorganics
pH	Low pH indicates presence of volatile free fatty acids		

Fugitive dust and runoff - Runoff and overflow from piles or sludge ponds should be treated as fugitive sources and be sampled when and where they occur. For runoff or overflow the receiving water segment should be sampled immediately to assess the effect of the added pollutant loading. Fugitive dust samples are in the form of particulates and are treated in the same manner as discussed in the section on air sampling. Samples are collected with Hi-Vol samplers or dustfall buckets. These devices can trap total suspended particulates (TSP) or all particles below a certain critical size. Therefore, the fugitive dust can be sampled for size as well as for chemical composition.

Analytical Techniques

Introduction - A plethora of techniques exist which can be used in the analysis of waste stream samples. The decision involved in selecting the appropriate analytical methods for any situation must be based upon the criteria delineated in Table 9. A further consideration to those listed is the necessity to compare results obtained using different techniques. For instance, in determining trace element emissions to air

Table 9. CRITERIA FOR SELECTION OF ANALYTICAL METHODS

Requirement	Definition	Relative importance in qualitative analysis	Relative importance in quantitative analysis
Sensitivity	Amount of material that gives a specified response.	High - Being able "to see" any substance on first analysis can save considerable time in later testing	High - Must be able "to see" at least down to lowest level of concern.
Specificity	Ability to measure only the substance of interest by eliminating interferences.	Low - Detecting even a "hint" of a species is important in screening. Later tests can provide confirmation.	High - Interference can cause erroneous data interpretation.
Precision	Error of the method (often expressed as the coefficient of variation) established by the analysis of many samples containing equivalent amounts of the species of interest.	High - Lack of precision can make a test useless.	High - Lack of precision can make a test useless.
Accuracy	Ability to determine the true value.	Low - An order of magnitude accuracy would be adequate.	High - Should be good to within 100% at parts per billion; 50% at parts per million.
Range of analysis	Concentration range in which reliable results can be obtained.	High - Ideally, a range which spans 10^{-9} to 10^{-3} g-mole/ℓ is desirable.	Low - Screening tests should allow one to preselect optimum range of interest; hence flexibility here is not important.
Stability	Ability of the materials to remain intact over a period of time.	High - Consistency is important in screening tests; instability can also affect precision.	Moderate - One will often have option of selecting optimum time for analysis; hence problems of instability may be avoided.
Ease of handling	Skills required to prepare the sample and execute the analytical methods.	Moderate - Convenience and speed are important in screening tests. Methods requiring advanced skills tend to reduce precision.	Moderate - The importance of the final result should dictate the level of effort.
Response time	Time required to analyze one sample completely.	Moderate - Again convenience is high priority, but low response time could be traded off against ability to measure many different species.	Moderate - Same as in qualitative.
Cost	Actual monetary expenditure for materials, equipment, and personnel needed.	Examination of numerous samples requires low cost per sample.	Cost can vary with the importance of the result.
Availability of equipment	Ability to purchase the required equipment and materials needed for an analysis.	High - When many tests are to be performed, one needs easily available supplies.	Moderate - Most important samples can receive special priority.

and water streams it is important to select techniques of comparable sensitivity; otherwise erroneous conclusions may be drawn as to the media distribution of the element of interest.

The criteria in Table 9 will be weighted differently for qualitative and quantitative analyses. Although the same instrumentation can often be used for both types of analyses, in the former, sensitivity, speed, and ease of performance are crucial, while for the latter, precision, accuracy, and specificity are needed.

For criteria pollutants (see Appendix D) specific analytical techniques - the Federal Reference Methods - have been established and should be used.

Air, water, and solid samples can often be analyzed by the same technique. For example, techniques such as gas chromatography-mass spectrometry (GCMS), atomic absorption analysis (AA), and infrared spectroscopy (IR) can be applied to samples from any medium.

The cost of using an analytical technique is important. Generally, the greater the accuracy of a technique, the higher the cost per analysis. Analysis cost per sample can generally be reduced by analyzing many samples by the same technique. Therefore, analytical techniques should be chosen with the broadest possible applications in mind.[14,15]

Methodologies for planning and fabricating a high efficiency analysis campaign are available. These are based on the analytical resources available and a priority ranking for measuring hazardous emissions. These methodologies should be consulted at the beginning of any analytical program.[16,17,18]

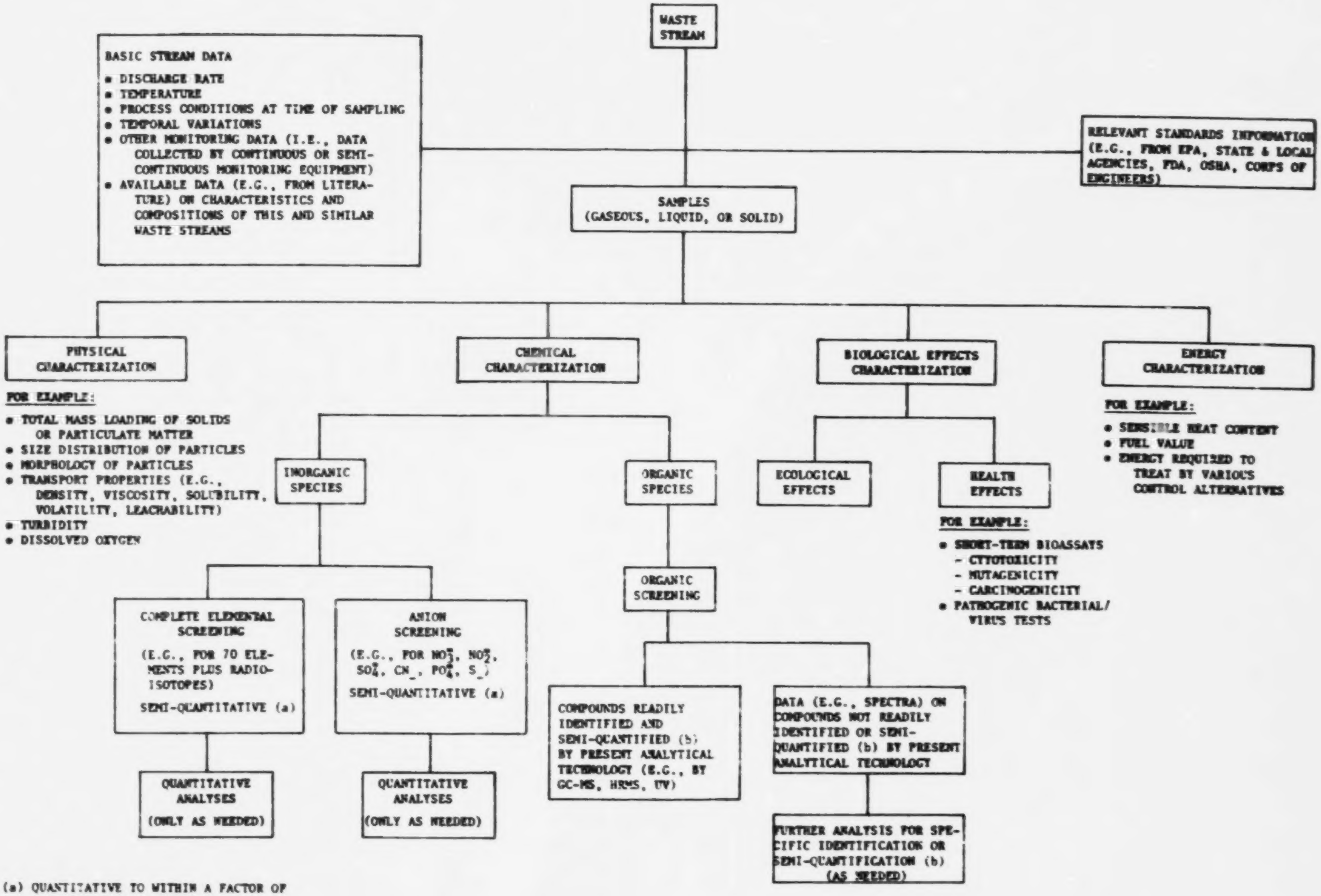
Figure 17[19] presents a flow chart of the steps required for collecting waste stream data in an environmental assessment for one such methodology. The extent to which the tasks in Figure 17 are employed will depend on both the goals of the assessment and the cost of the analyses. For assessments including comprehensive source tests, it is suggested that the main tasks in Figure 17 (physical, chemical, biological, and energy characterization) receive equal priority. Figure 18 suggests techniques which can be employed in waste stream analysis. For each category it is suggested that a minimum of two samples should be comprehensively characterized for each waste stream and each different, but significant, operating condition of the system.

AMBIENT TESTS

Introduction

The purpose of an ambient testing program is to measure the concentrations of pollutants in the air, water, or soil in the vicinity of a pollutant source. (In the context of an environmental assessment of energy systems, ambient refers to those sectors of the environment beyond the actual site of the system.) Ambient tests are essential since they are the only definitive means of determining the chemical and physical composition of effluents in the environment. Ambient tests are also a necessary adjunct to source tests and dispersion models since the data from the two sets of experiments can be used to identify the modes of pollutant transport and conversion.

Ambient testing differs from source testing in several significant ways: (1) the logistics in an ambient program are generally more complicated (more monitoring sites, instrumentation, personnel, etc.), (2) the influence of factors such as terrain and weather conditions must be taken into account, (3) the concentration levels are often small enough (part per billion or part per trillion) to dictate special sampling and


WASTE STREAM
BASIC STREAM DATA
• DISCHARGE RATE
• TEMPERATURE
• PROCESS CONDITIONS AT TIME OF SAMPLING
• TEMPORAL VARIATIONS
• OTHER MONITORING DATA (I.E., DATA COLLECTED BY CONTINUOUS OR SEMI-CONTINUOUS MONITORING EQUIPMENT)
• AVAILABLE DATA (E.G., FROM LITERATURE) ON CHARACTERISTICS AND COMPOSITIONS OF THIS AND SIMILAR WASTE STREAMS
RELEVANT STANDARDS INFORMATION (E.G., FROM EPA, STATE & LOCAL AGENCIES, FDA, OSHA, CORPS OF ENGINEERS)
SAMPLES (GASEOUS, LIQUID, OR SOLID)
PHYSICAL CHARACTERIZATION
FOR EXAMPLE:
• TOTAL MASS LOADING OF SOLIDS OR PARTICULATE MATTER
• SIZE DISTRIBUTION OF PARTICLES
• MORPHOLOGY OF PARTICLES
• TRANSPORT PROPERTIES (E.G., DENSITY, VISCOSITY, SOLUBILITY, VOLATILITY, LEACHABILITY)
• TURBIDITY
• DISSOLVED OXYGEN
CHEMICAL CHARACTERIZATION
BIOLOGICAL EFFECTS CHARACTERIZATION
ENERGY CHARACTERIZATION
FOR EXAMPLE:
• SENSIBLE HEAT CONTENT
• FUEL VALUE
• ENERGY REQUIRED TO TREAT BY VARIOUS CONTROL ALTERNATIVES
INORGANIC SPECIES
ORGANIC SPECIES
ECOLOGICAL EFFECTS
HEALTH EFFECTS
FOR EXAMPLE:
• SHORT-TERM BIOASSAYS
- CYTOTOXICITY
- MUTAGENICITY
- CARCINOGENICITY
• PATHOGENIC BACTERIAL/VIRUS TESTS
ORGANIC SCREENING
COMPLETE ELEMENTAL SCREENING
(E.G., FOR 70 ELEMENTS PLUS RADIOISOTOPES)
SEMI-QUANTITATIVE (a)
ANION SCREENING
(E.G., FOR NO_3^-, NO_2^-, $SO_4^=$, CN_-, $PO_4^=$, S_-)
SEMI-QUANTITATIVE (a)
QUANTITATIVE ANALYSES (ONLY AS NEEDED)
QUANTITATIVE ANALYSES (ONLY AS NEEDED)
COMPOUNDS READILY IDENTIFIED AND SEMI-QUANTIFIED (b) BY PRESENT ANALYTICAL TECHNOLOGY (E.G., BY GC-MS, HRMS, UV)
DATA (E.G., SPECTRA) ON COMPOUNDS NOT READILY IDENTIFIED OR SEMI-QUANTIFIED (b) BY PRESENT ANALYTICAL TECHNOLOGY
FURTHER ANALYSIS FOR SPECIFIC IDENTIFICATION OR SEMI-QUANTIFICATION (b) (AS NEEDED)

(a) QUANTITATIVE TO WITHIN A FACTOR OF 2 OF THE TRUE CONCENTRATION.
(b) QUANTITATIVE TO WITHIN A FACTOR OF 10 OF THE TRUE CONCENTRATION.

Figure 17. Diagram summarizing the types of basic stream data to be collected for environmental assessments (taken from reference 19)

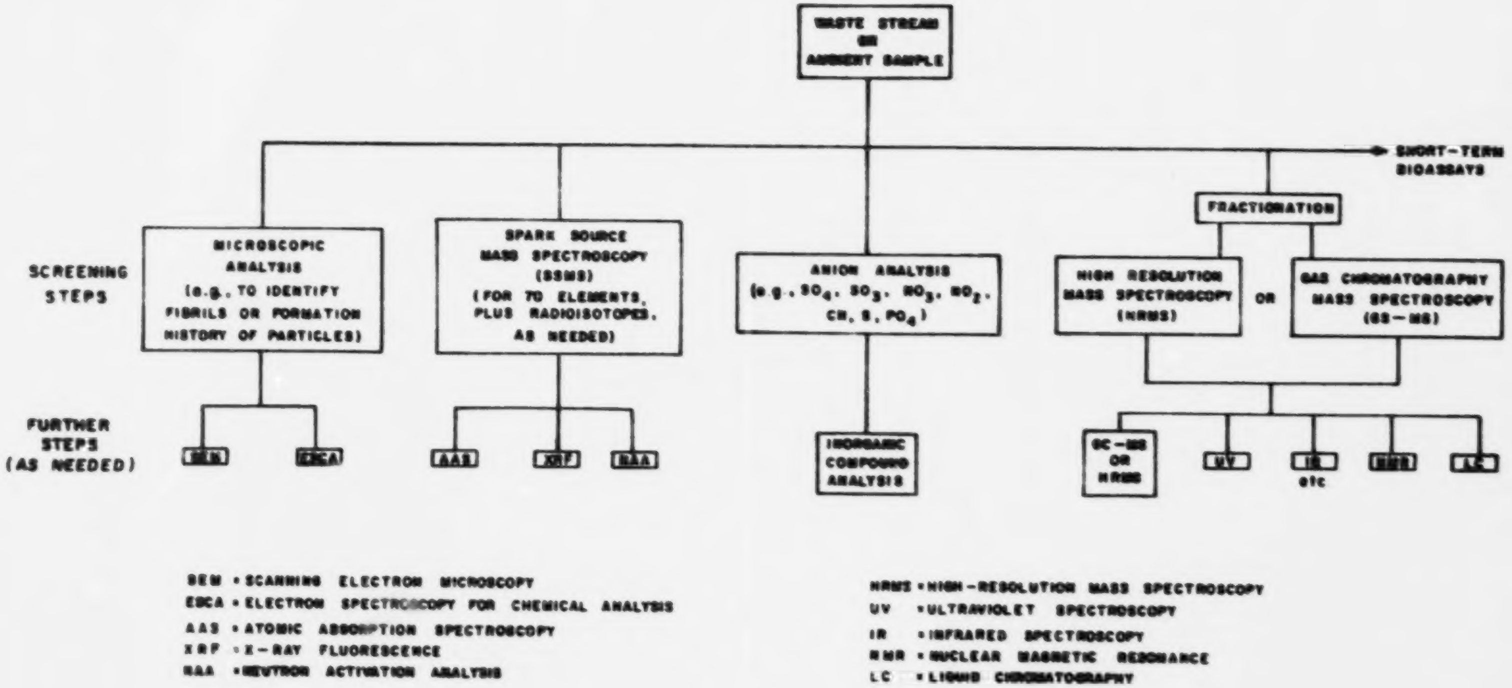

WASTE STREAM
OR
AMBIENT SAMPLE
SHORT-TERM BIOASSAYS
SCREENING STEPS
MICROSCOPIC ANALYSIS (e.g., TO IDENTIFY FIBRILS OR FORMATION HISTORY OF PARTICLES)
SPARK SOURCE MASS SPECTROSCOPY (SSMS) (FOR 70 ELEMENTS, PLUS RADIOISOTOPES, AS NEEDED)
ANION ANALYSIS (e.g., SO_4, SO_3, NO_3, NO_2, CN, S, PO_4)
FRACTIONATION
HIGH RESOLUTION MASS SPECTROSCOPY (HRMS)
OR
GAS CHROMATOGRAPHY MASS SPECTROSCOPY (GS-MS)
FURTHER STEPS (AS NEEDED)
SEM
ESCA
AAS
XRF
NAA
INORGANIC COMPOUND ANALYSIS
GC-MS OR HRMS
UV
IR
etc
NMR
LC
SEM = SCANNING ELECTRON MICROSCOPY
ESCA = ELECTRON SPECTROSCOPY FOR CHEMICAL ANALYSIS
AAS = ATOMIC ABSORPTION SPECTROSCOPY
XRF = X-RAY FLUORESCENCE
NAA = NEUTRON ACTIVATION ANALYSIS
HRMS = HIGH-RESOLUTION MASS SPECTROSCOPY
UV = ULTRAVIOLET SPECTROSCOPY
IR = INFRARED SPECTROSCOPY
NMR = NUCLEAR MAGNETIC RESONANCE
LC = LIQUID CHROMATOGRAPHY

Figure 18. Illustrative chemical analysis strategy for environmental assessments (reference 19)

analytical techniques, and, (4) the pollutants of interest can be different in source and ambient tests. This latter point is important. For example, elemental mercury emitted by a source may be biologically transformed into more toxic methyl and phenyl mercury by marine organisms. Also, photochemical reactions in the atmosphere of species such as hydrocarbons can form new pollutants such as peroxyacetyl nitrate (PAN) or oxygenated hydrocarbons.

Ambient Monitor Siting

Presented below are several examples which qualitatively illustrate the manner in which variables related to the site and the pollutant can affect the design of an ambient monitoring program.

- Climatology - An understanding of the climatology of a particular area is essential for the development of a monitoring program. This is especially important for the measurement of air pollutants whose dispersion depends on local climatological features such as inversions, sea breezes, and inversion breakups. Meteorological variables such as wind speed and ambient temperature determine buoyant plume rise. A frequency distribution of wind direction is used as an aid in the placement of monitors. The choice of radial distances from the stack for monitor placement is complex and depends upon variables such as effective stack height, wind speed, and atmospheric stability.

  The percentage of time rainfall occurs and the average rainfall rate will give some indication of the amount of wet deposition which takes place over a period of time and the detectability of the corresponding pollutant enrichment factor in the top layers of soil by standard measurement techniques. The climatological parameters of seasonal rainfall distribution and average windspeed are important considerations in the design of any system to monitor fugitive dust from natural or man-made sources.

- Hydrology - Since the flow of water is one of the major mechanisms for pollutant transport, a study of the hydrological characteristics in the vicinity of an energy system should be conducted before the design of a monitoring system. The first phase of such a study would be an analysis of: (1) the various pathways by which precipitation within a watershed finds its way to a receiving body of water such as a stream or lake; and (2) the relative importance of each of these pathways for the area in question. A second phase of the hydrological survey would be a characterization of water bodies in the area as to their geometry, flow rates, and relationship to one another.

Information gained from this survey is valuable in the selection of water monitoring locations. Estimates of stream flow and turbulent diffusivity are utilized to insure that a monitoring site is situated far enough downstream from the point of effluent input so that the pollutant concentrations are relatively uniform over the stream cross section.

- Topography - The nature of the topography of a site will exert obvious constraints upon the design of a sampling program. In mountainous or hilly terrain the placement of air samplers must be representative of the actual features of the local terrain so that no measurement site is cut off from any direct impact of pollutant emissions. The density of monitoring sites in a given direction should reflect the nature of the prevailing winds in the area, which is in turn affected by topographical features.

- Chemical and Biological Characteristics - One of the most important characteristics of a given pollutant in regard to the development of a monitoring system is its behavior under the processes of chemical and biological transformation. For example, suppose that a network to measure sulfate ($SO_4^=$) levels in the vicinity of an energy system were to be set up. Since the oxidation of the primary pollutant SO_2 to the secondary pollutant ($SO_4^=$) will proceed according to some finite reaction rate, the placement of monitors downwind from a point source would necessarily be different than those for nonreactive pollutant concentration measurements. The distance between SO_2 and ($SO_4^=$) ground level air concentration maxima will be functions not only of the chemical transformation rate but also the source height, wind speed, stability, and deposition rate. The possibility of pollutant transformation in the environment must always be considered.

Sampling and Analysis with Respect to Ambient Testing Programs

Logistics - An ambient test program involves multiple monitoring sites, thus special attention should be devoted to the logistics of monitor placement. Prior to actual site selections, surveys should be conducted with mobile monitoring stations to assist in site selection. Mobile monitoring stations should always be used to complement any pre-existing permanent stations.

In many cases, traversing rugged terrain may be a necessary aspect of a test program. Small, rugged, and portable instrumentation then becomes desirable. Under such conditions, particularly durable sampling materials may be required. In some cases the use of heavy duty materials (e.g., metal containers versus glass) although providing increased ease of handling may introduce added sampling errors. Such a situation calls for at least a crude cost/analysis (e.g., can the added error be tolerated in view of the fact that the data can be gathered more readily).

Transporting samples back to a central laboratory is often troublesome. The option of using a mobile analytical laboratory should be considered. The analytical techniques may be unsophisticated, but the reduction of sample deterioration can sometimes counterbalance any advantage gained from more sophisticated analysis. For instance, in some water pollution analyses, the use of a series of specific ion electrodes may be adequate for any elemental analyses.

A judicious degree of uniformity is necessary in an ambient test program. Obviously, this applies to the types of instrumentation and equipment used. For example, using different techniques to measure SO_2 at different monitoring sites is inappropriate. Uniformity should extend to the whole monitoring campaign including the height at which air samples are taken (or the depth for water samplers), the frequency of maintenance or calibration checks, the time delay between sampling and actual analysis.

Concentration Levels - The ambient concentration of many pollutants is extremely small; parts per billion (ppb) and parts per trillion (ppt) are common. Consequently, either simple concentration techniques or sensitive analytical techniques are required for an adequate monitoring program. If in some cases a sample cannot be concentrated, techniques such as the standard additions method, which can effectively extend the lower detection limit of the analytical technique, are required.

Tables 10 and 11 provide some indication of the concentration levels of various chemicals which are encountered in ambient testing. Table 10 is a useful benchmark, as it provides examples of ambient air pollutant levels which have been measured in various geographic areas. Table 11 provides similar data for water pollutants.

In reviewing these tables one significant fact becomes apparent - the prevailing levels of pollutants vary considerably from region to region. For example, the concentration of ethylene in downtown Washington is a factor of 20 greater than that in a rural area. The ambient level of strontium in the Tennessee River is 47 $\mu g/\ell$, but in the Colorado River it is 647 $\mu g/\ell$. Having at least an estimate of the expected baseline concentrations can help considerably in setting analytical requirements (at the ppb level, an order of magnitude increase in sensitivity can be very costly).

Monitoring Techniques - The discussion concerning sampling and analysis with respect to source tests also applies to ambient tests; i.e., the remarks concerning presampling surveys, sampling precautions, use of qualitative versus quantitative analytical techniques, etc. are equally valid here. Excellent texts describing analytical and instrumental methods for ambient pollutant analysis are available; for air, references 3, 29, 31, 40 to 45; for water, references 13, 14, 32, 33,

Table 10. BACKGROUND CONCENTRATIONS FOR AIR POLLUTANTS

Pollutant	Ambient concentration	Comment	Ref.
Gases:			
Ammonia	20 μg/m^3 (0.03 ppm)	National average	20
	1 to 75 μg/m^3 (0.002-0.1 ppm)	National range	
CO	6-17 mg/m^3 (5-15 ppm)	Typical urban CO concentration	21
Hydrocarbons:			
Methane	1.3-2.6 mg/m^3 (2-4 ppm)	Urban concentrations based on data taken in Los Angeles	22
	0.8-0.9 mg/m^3 (1.2-1.4 ppm)	Rural concentration	22
Total hydrocarbon	3-5 ppm	Downtown Los Angeles	22
Nonmethane	(~1.5-2.5 ppm)	Downtown Los Angeles	22
Ethylene	6 μg/m^3 (<5 ppb)	Rural areas	23
	45-800 μg/m^3 (39-700 ppb)	Outside and inside Washington, D.C.	23
Hydrogen sulfide	0-55 μg/m^3 (0-40 ppb)	National range	24
Nitrogen oxides	0.4-7.5 μg/m^3 (~0.2-4 ppb)	Rural areas	21
	0.2 mg/m^3 (~0.1 ppm)	Large cities	21
Oxidants			
Ozone	20-100 μg/m^3 (10-50 ppb)	Background concentration as hourly average	25
	20-140 μg/m^3 (10-70 ppb)	Rural area upwind of urban source	25

Table 10 (continued). BACKGROUND CONCENTRATIONS FOR AIR POLLUTANTS

Pollutant	Ambient concentration	Comment	Ref.
	200-1000 µg/m^3 (100-500 ppb)	Peak concentrations in urban source	24
PAN	10-41 µg/m^3 (23-9.6 ppb)	Southern Calif.	25
	130 µg/m^3 (30 ppb)	Eastern Los Angeles	25
	65 µg/m^3 (<15 ppb)	Average	25
Sulfur dioxide	2-113 mg/m^3 (0.8-43 ppm)	Annual average range. Concentration highly dependent on monitoring site	26
Aerosols:			
Acid mist; sulfuric acid	4.5 µg/m^3	Level found in American cities	27
Arsenic	0.1 to 1.0 µg/m	Uninhabited areas	28
Hydrocarbons;	0.0028 µg/m^3	Urban areas	3
Benzo (a) Pyrene	0.00035 µg/m^3	Rural areas	
Mercury	<1 µg/m^3	Maximum allowed limits	29
Total suspended particulates	60 to 220 µg/m^3	Urban areas	30
	10 to 60 µg/m^3	Rural areas	30

Table 11. OBSERVED MEAN POSITIVE TRACE METAL VALUES BY BASIN[32]
(μg/ℓ)

	Northeast	North Atlantic	Southeast	Tennessee River	Ohio River	Lake Erie	Upper Mississippi	Western Great Lakes	Missouri River	Southwest Lower Mississippi	Colorado River	Western Gulf	Pacific Northwest	California	Great Basin	Alaska
Zn	96	49	52	28	81	205	45	24	39	85	51	92	40	16	44	28
Cd	5	3	5	-	7	50	6	5	-	-	2	10	5	-	1	-
As	34	47	35	50	66	308	69	37	123	91	53	22	68	-	20	34
B	32	42	29	24	67	210	105	19	154	131	179	289	30	143	84	28
P	44	48	43	42	130	153	243	31	353	81	121	173	47	83	37	40
Fe	51	19	120	37	28	35	35	22	37	69	40	173	32	46	70	25
Mo	25	33	15	25	70	68	88	28	83	95	130	24	30	45	145	17
Mn	3.5	2.7	2.8	3.7	232	138	9.8	2.3	13.8	9.0	12	10	2.8	2.8	7.8	18
Al	28	22	117	30	141	56	18	17	213	68	50	333	30	63	15	11
Be	0.02	0.12	0.05	0.16	0.28	0.17	-	0.05	0.23	-	-	-	0.02	-	-	-
Cu	15	17	14	11	23	11	14	7	17	19	10	11	9	12	12	9
Ag	1.9	0.9	0.4	-	2.1	5.3	3.4	1.4	1.2	4.3	5.8	3.5	0.9	-	0.3	1.1
Ni	8	8	4	4	31	56	15	10	5	17	12	3	10	10	4	5
Co	14	9	1	-	19	33	18	11	8	36	11		8	-	-	-
Pb	17	14	8	17	30	39	33	14	39	37	32	4	15	4	18	12
Cr	14	6	4	6	7	12	7	6	17	16	16	25	6	15	4	9
V	9	12	10	-	22	54	20	-	171	25	105	9	13	30	-	32
Ba	21	25	26	25	43	42	39	15	63	90	60	67	27	42	41	17
Sr	76	62	26	47	130	260	105	44	342	540	697	652	68	153	152	81

35 to 39; for solids, references 8, 11, 34. These references provide information on sampling and analysis requirements and precautions, and should be consulted in the preparation of any ambient monitoring program.

Identifying Source Background Contaminants

A primary requisite for a monitoring program associated with energy system development and operation is the capability of separating the influence of background sources in air, solid, and water quality measurements. One way in which this objective can be realized is to carry out a measurement program before the initial construction phase of the energy system. This procedure may not be applicable in the case of atmospheric transport, however, because the background concentrations during this measurement period may not be representative due to variations in meteorological conditions or the growth of new emission sources in the area.

A more useful technique for air pollution measurements would be the construction of a "pollutant rose" based upon measurements taken during the operation of the energy system. This method of analysis involves the construction of a frequency distribution of wind directions and pollutant concentrations for a number of monitoring stations in the area. Figure 19 gives a graphical representation of this type of distribution for several SO_2 monitoring stations. The length of each barb is proportional to the mean of concentrations measured when the wind direction is in the direction toward which the barb is pointing. The length of the barb can be converted to concentration by means of the scale at the right of the figure. The radius of the circle represents the mean of all concentrations measured at the station during the time period of interest. The example chosen shows a significant amount of background not attributable to the power station. The longest barbs would point toward the power station if the highest or second highest hourly SO_2 concentrations were

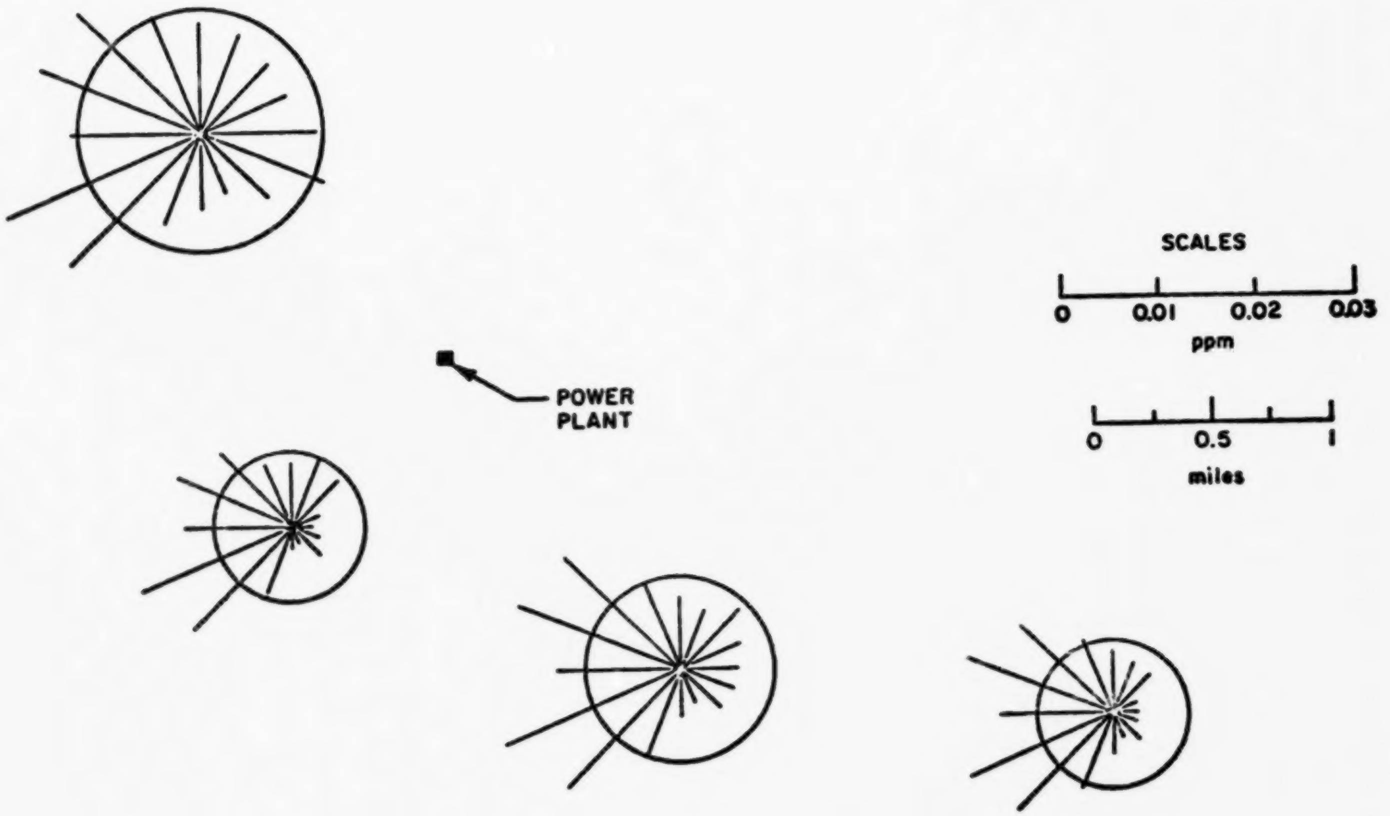


Figure 19. Illustration of pollutant roses for SO_2

displayed, instead of the geometric mean. In the case of suspended particulates, another method for the separation of source and background contributions is through a source/receptor characterization study in which material collected at sampling locations would be categorized according to parameters such as size distributions, physical shape, and chemical composition and could be related to corresponding emission characteristics obtained from source testing.

DEVELOPMENT OF QUALITY CONTROL PROGRAM

Introduction

In view of the preceding discussion of the technology involved in both sampling and analyzing waste streams, it is important to outline steps which should be taken to insure adequate quality control of the data. Any numerical value is virtually useless unless some measure of its reliability is available.

Figure 20 presents an outline of the tasks and responsibilities of a data quality control program in the form of a "quality assurance wheel."[46] The wheel illustrates the requirements of a quality assurance system and groups quality assurance elements according to the organizational level to which responsibility is normally assigned. This section outlines briefly some of the more important tasks in Figure 20. For a comprehensive discussion of the requirements of a quality assurance program, reference 46 should be consulted.

Major Features of a Quality Control Program

Planning is essential for insuring data quality; in general, the larger the environmental assessment program, the more detailed the planning should be.

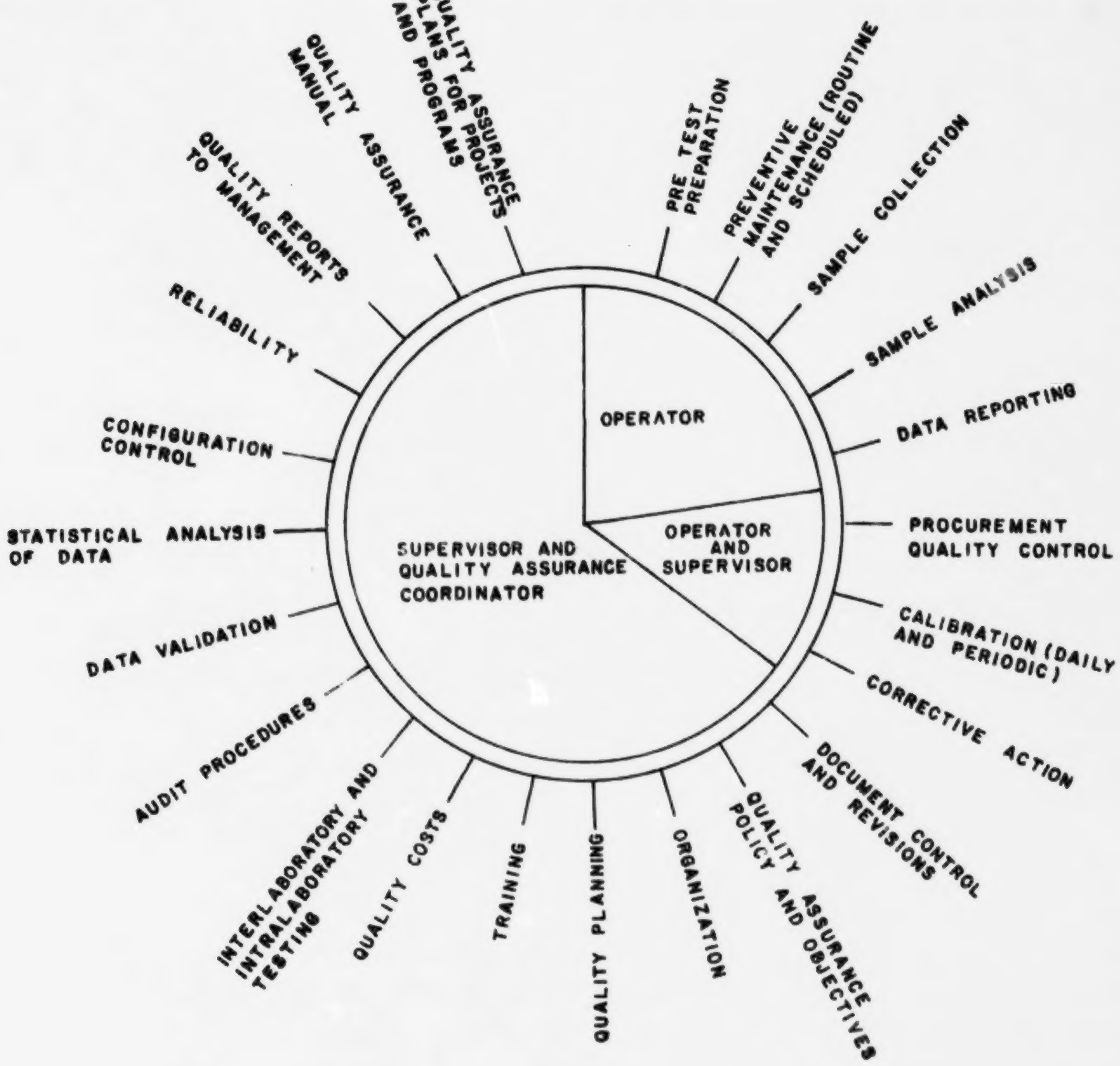

QUALITY ASSURANCE PLANS FOR PROJECTS AND PROGRAMS
PRE TEST PREPARATION
PREVENTIVE MAINTENANCE (ROUTINE AND SCHEDULED)
SAMPLE COLLECTION
SAMPLE ANALYSIS
DATA REPORTING
PROCUREMENT QUALITY CONTROL
CALIBRATION (DAILY AND PERIODIC)
CORRECTIVE ACTION
DOCUMENT CONTROL AND REVISIONS
QUALITY ASSURANCE POLICY AND OBJECTIVES
ORGANIZATION
QUALITY PLANNING
TRAINING
QUALITY COSTS
INTERLABORATORY AND INTRALABORATORY TESTING
AUDIT PROCEDURES
DATA VALIDATION
STATISTICAL ANALYSIS OF DATA
CONFIGURATION CONTROL
RELIABILITY
QUALITY REPORTS TO MANAGEMENT
QUALITY ASSURANCE MANUAL
OPERATOR
OPERATOR AND SUPERVISOR
SUPERVISOR AND QUALITY ASSURANCE COORDINATOR

Figure 20. Quality assurance elements and responsibilities (the quality assurance wheel - reference 46)

The aim here is only to provide highlights of those features which should be included in any quality control program. For further detail, the user should consult the various EPA Handbooks on Quality Control.[46-48] The major elements which are essential for quality control are:

- Organization - In all cases, a clear outline of the project's organization and the lines of responsibility should be provided.
- Document Control - Procedures used in sample collection, sample analysis, calibration, etc., should be placed under document control and a record of distribution maintained so that whenever changes in procedures are required, all concerned participants will receive copies.
- Sample Collection - Detailed written procedures for sample handling and storage should be provided for each type of measurement in the program.
- Sample Analysis - Detailed written procedures for analytical techniques should also be provided for each measurement in the program.
- Data Reporting - Procedures must be established for reporting data. In general, preprinted data forms are preferred. Supplementary information which should be reported includes experimental parameters such as flow rates, temperatures, weather conditions (if appropriate), time of measurement, etc. The reported data should also be consistent as to when averages, means, medians, etc. are reported. In all cases, the number of samples, precision and best estimate of error should be supplied at the time of measurement.
- Data Validation - Specific criteria for validation of data must be provided. This can include limits for precision, accuracy (compared with known values) and experimental parameters (flow rates, temperature, etc.). Included here should also be the specification of those actions that should be taken if data seem invalid (e.g., rejection, repetition of measurements, inclusion with special notation, etc.).
- Auditing Procedures - Detailed plans for audits should be specified; this includes identifying the critical characteristics of the measurement which should be audited, the size and frequency of the audit, the manner in which individual auditing checks will be performed, and the control limits for passing the audit (usually within 3 times the

standard deviation from the calculated average value). The major difficulty here is setting the audit size. Seven percent of the total has been suggested as a reasonable criterion, but in many cases this will be subject to cost constraints.

- Calibration - The types of calibration standards to be used and a recommended schedule for calibration should be established. This is one of the most crucial aspects of the quality control program. In general, calibration standards should have about 10 times the accuracy of the measurement equipment being tested. Whenever possible, U.S. National Bureau of Standards (NBS) Standard Reference Materials (SRM) should be used. Reference 49 provides useful background information for calibration procedures.
- Preventive Maintenance - A recommended schedule for maintenance checks should be provided.
- Interlaboratory Tests - Any planned or anticipated participation in interlaboratory tests should be indicated.
- Reports - Indicate the type of information planned for the reports and the frequency of reporting.

Decisions Based on Quality Control Tests

The crucial phase of the quality control effort will be the decision as to which data are to be included in the assessment program. The decision-making domain encompasses two general areas: that which is related to the so-called "new" data (i.e., data generated during the course of the program), and that related to "old" data (i.e., that which is already available before the initiation of the program, as one might encounter, for example, in a preliminary environmental assessment).

New Data - If simple quality control tests are passed (i.e., the data indicate negligible trends, acceptable variations in precision, etc.), the results can be considered valid and incorporated in the report. If the simple tests are not passed, more sophisticated analyses should be employed to determine the cause of the variation. Assuming the cause for rejection can be identified, a decision must be made as to whether new measurements should be taken or whether the uncertainty should be incorporated in the data and appropriate error limits cited. Criteria on which such a decision would be based include: (1) the availability of relevant monitoring technology, (2) the cost of performing new measurements, and (3) the relative importance of the data under consideration. For example, if there is an unexplained trend in data obtained from NO_x measurements in a stack using chemiluminescence detection techniques, it is a relatively easy matter to perform similar measurements using colorimetric devices which may provide better data. On the other hand, if there is some unexplained trend in data obtained from ground level measurements of the dispersion of NO_x from a stack, the cost of repeating the measurements could prohibit further experiments and the data would be used with appropriate error limits cited.

Old Data - Whenever old data is to be used, it must first be assessed in terms of its susceptibility to error. In making this decision, important questions to consider include: (1) were proper techniques used in obtaining the data (e.g., was the measurement technique vulnerable to potentially interfering species known to be present in the sample, or was the measurement technique sensitive enough for the concentration range of interest); (2) were proper procedures followed in obtaining the data (e.g., use of proper calibration standards, reliable sampling systems, use of sensible time scales to prevent sample degradation, etc.). Old data which prove suspicious simply on the basis of techniques employed or procedures followed should not be used. Old data deemed acceptable for further evaluation would then be subjected to spot checks using the simple quality control tests previously described. If the data passes these tests it can be incorporated into the report. If it does not pass these tests there is, once more, the choice of repeating the measurements or simply incorporating the data in the report with the appropriate error assessment discussed.

Reporting Error

A common manner of expressing the error which may be inherent in a set of measurements is to quote the standard deviation of the results.

It is, however, more important to estimate error limits which, in the estimation of program personnel, are unlikely to be exceeded. This, of course, will include an appropriate discussion of the rationale used in estimating the limits. Typical features entering into such a discussion are: (1) identification of the major source of error (e.g., systematic versus random); (2) appraisal of the short-term and long-term possibilities for obtaining improved values; and (3) identification of situations where unusual caution is required in using reported values.

Cost of Reducing Errors

In practice, cost constraints limit the effort which may be expanded to reduce errors in any program. Ideally, a detailed cost/benefit analysis would be applied to any situation calling for a decision as to whether or not further error reduction is required. A lengthy explanation of cost/benefit analysis is beyond the scope of the project. However, a simple example may convey the main thrust of a cost/benefit analysis. If a hundred data points exist and it is assumed that only random error is present, the resulting precision is 10 percent.[*] To improve the precision to 1 percent under the same conditions would require 9,900 more data points. Assuming the cost of each data point is equal, one gains a factor of 10 in precision but only by increasing the cost a factor of 100. In many cases this extra cost may not be justified.

---

[*] Precision = $(1/\sqrt{N}) \times 100$ where N is the number of data points.

REFERENCES

1. Standards of Performance for New Stationary Sources. Federal Register, 36-247, December 23, 1971.

2. Standards of Performance for New Stationary Sources. Code of Federal Regulations, 40 CFR, Part 60, May 23, 1975.

3. Methods of Air Sampling and Analysis. American Public Health Association. Washington, D.C. 1972.

4. Hamil, H.F. and D.E. Camann. Collaborative Study of Method for the Determination of Sulfur Dioxide Emissions from Stationary Sources (Fossil-Fuel-Fired Steam Generators). U.S. Environmental Protection Agency, Raleigh, N.C. Publication Number EPA 650/4-74-024. Southwest Research Institute, December 1973.

5. Epstein, R.E. Field Evaluation of an SO_2 In-Stack Correlation Spectrometer, 65th Annual Air Pollution Control Association Meeting, Miami Beach, Florida, 1972.

6. Zaromb, S. et al. Proceedings of the Second International Clean Air Congress. Berry, W. T. and H. M. Englund (eds.). Academic Press, 1971.

7. Smith, F., and C. Nelson, Jr. Guidelines for Development of a Quality Assurance Program - Reference Method for Determination of Suspended Particulate in the Atmosphere (Hi-Vol Method). U.S. Environmental Protection Agency, Research Triangle Institute, Research Triangle Park, N.C., report for U.S. Environmental Protection Agency, Publication No. EPA-RA-73-0286, June 1973.

8. Methods for Chemical Analysis of Water and Wastes. Methods Development and Quality Assurance Research Laboratory, National Environmental Research Center, USEPA Office of Technology Transfer. Publication Number EPA-625/6-74-003. 1974.

9. Keith, L. H. USEPA, Southeast, Environmental Research Laboratory, Athens, Georgia. (private communication).

10. Geswein, A. J. Liners for Land Disposal Sites, An Assessment. U.S. Environmental Protection Agency, Raleigh, N.C. Publication Number EPA/530 SW-137. 1975.

11. Edward, S. K. Chian, and Foppe B. DeWolle. Compilation of Methodology Used for Measuring Pollution Parameters of Sanitary Landfill Leachate. Preliminary Report. Environmental Engineering Section, Department of Civil Engineering, University of Illinois, Urbana. U.S. Environmental Protection Agency, Office of Research and Development. 1974.

12. Hazo, H. E., and R. M. White. Matrecon Inc. Evaluation of Liner Materials Exposed to Leachate. First Interim Report. U.S. Environmental Protection Agency, Raleigh, N.C. Contract Number EPA 68-03-2134, 1974.

13. Methods for Chemical Analysis of Water and Wastes. Methods Development and Quality Assurance Research Laboratory, National Environmental Research Center, USEPA Office of Technology Transfer. Publication Number EPA-625/6-74-003. 1974.

14. Survey of Various Approaches to the Chemical Analysis of Environmentally Important Materials. U.S. National Bureau of Standards. Publication Number COM-74-10469. Environmental Protection Agency, Raleigh, N.C., July 1973.

15. Yen, T. F. The Role of Trace Metals in Petroleum. Ann Arbor, Michigan, Ann Arbor Science Publishers, Inc., 1975.

16. Bombaugh, K. J., E. C. Cavanaugh, (Radian Corporation), and A. Jefcoat (EPA). A Systematic Approach to the Problem of Characterizing the Emission Potential of Energy Conversion Processes. (Presented at the 80th National Meeting of the AIChE. Boston, Massachusetts. September, 1975.)

17. Cavanaugh, E. C., C. E. Burklin, J. C. Dickerman, H. E. Lebowitz, S. S. Tam, and G. R. Smithson. Potentially Hazardous Emissions from Extraction and Processing of Coal and Oil. Battelle Columbus Laboratories report for U.S. Environmental Protection Agency, Raleigh, N.C. Publication Number EPA 650/2-75-038, 1975.

18. Bombaugh, K. J., E. C. Cavanaugh, J. C. Dickerman, S. L. Keil, T. P. Nelson, M. L. Owen and D. D. Rosebrook. Sampling and Analytical Strategies for Compounds in Petroleum Refinery Streams. Radian Corp., report for U.S. Environmental Protection Agency, Raleigh, N.C. Publication Number EPA 68-02-1882, September, 1975.

19. Tucker, W. G., S. J. Bunas, J. A. Dorsey, J. A. McSorley and M. Samfield. Environmental Assessment Guideline Document. Draft Report, May 1975. Industrial and Environmental Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, N.C.

20. Miner, Sydney. Preliminary Air Pollution Survey of Ammonia - A Literature Review. Litton Systems, Inc. Environmental Systems Division, report for National Air Pollution Control Administration, Publication Number APTD 69-25. U.S. Department of Health, Education, and Welfare, October 1969.

21. Berry, R. S. and P. A. Lehman. Aerochemistry of Air Pollution. Annual Review of Physical Chemistry. 22:47-84, 1971.

22. Altshuller, A. P., W. A. Lonneman, and S. L. Kopczynski. Nonmethane Hydrocarbon Air Quality Measurements. JAPCA. 23(7):597-599. July 1973.

23. Abeles, F. B., and H. E. Heggestad. Ethylene: An Urban Air Pollutant. JAPCA. 23(6):517-521.

24. Forrest, J., and L. Newman. Ambient Air Monitoring for Sulfur Compounds - A Critical Review. JAPCA. 23(9). September 1973.

25. Corn, M., R. W. Dunlap, L. A. Goldmuntz, and L. H. Rogers. Photochemical Oxidants: Sources, Sinks and Strategies. JAPCA. 25(1):16-18. January 1975.

26. Thompson, C. R., E. G. Hensel, and G. Kats. Outdoor-Indoor Levels of Six Air Pollutants. JAPCA. 23, 1973.

27. Megannell, W. H. Atmospheric Sulfur Dioxide in the United States. JAPCA. 25(1):9-15. January 1975.

28. Saringelli, F. P., and K. A. Rehme. Determination of Atmospheric Concentrations of Sulfuric Acid Aerosol by Spectrophotometry, Coulometry, and Flame Photometry. Anal Chem. 41(6):107. 1969.

29. Sittig, M. Pollution Detection and Monitoring Handbook - 1974. McGraw Hill Book Company, Inc. New York.

30. Federal Register, 38(66):8820-8850, April 6, 1973.

31. Instrumentation for Environmental Monitoring - Air, LBL-1. Volume 1. Lawrence Berkeley Laboratory, University of California, Berkeley. December 1973.

32. Instrumentation for Environmental Monitoring - Water, LBL-1. Volume 2. Lawrence Berkeley Laboratory, University of California, Berkeley. December 1973.

33. Standard Methods for the Examination of Water and Wastewater. Prepared and published jointly by: American Public Health Association, American Water Works Association, and Water Pollution Control Federation. Thirteenth Edition. 1971.

34. Bender, D. F., M. L. Peterson and H. Stierli (eds.). Physical, Chemical, and Microbiological Methods of Solid Waste Testing. U.S. Environmental Protection Agency, Cincinnati, Ohio. Publication Number EPA-6700-73-01. May 1973.

35. Handbook for Monitoring Industrial Wastewater. Associated Water and Air Resources Engineers, Inc. Nashville, Tennessee. U.S. Environmental Protection Agency, Raleigh, N.C. August 1973.

36. Weber, C. I. (ed.). Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. Environmental Protection Agency, Cincinnati, Ohio. Publication Number EPA-670/4-73-001. July 1973.

37. Manual for Evaluating Public Drinking Water Supplies - A Manual of Practice. U.S. Environmental Protection Agency, Office of Water and Hazardous Substances. Former Publication Number PHS 1820. 1974.

38. Brown, E., M. W. Skongstad and M. J. Fishman. Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, Book 5. In: Chapter A1 of Techniques of Water Resources Investigations of the U.S. Geological Survey, 1974. Government Printing Office, 1972.

39. Goerli, D. F. and E. Brown, Book 5. Methods for Analysis of Organic Substances in Water. In: Chapter A3 of Techniques of Water Resources Investigations of the U.S. Geological Survey, 1972.

40. Smith, F., D. E. Wagoner, and A. C. Nelson Jr. Guidelines for Development of a Quality Assurance Program. In: Volume I, Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S-Pitot tube). U.S. Environmental Protection Agency, Quality Assurance and Environmental Monitoring Laboratory, Research Triangle Park, North Carolina. Publication Number EPA-650/4-74-005a. February 1974.

41. Smith, F. D. E. Wagoner, and A. C. Nelson, Jr. Guidelines for Development of a Quality Assurance Program. In: Volume II, Gas Analysis for Carbon Dioxide, Excess Air, and Dry Molecular Weight. U.S. Environmental Protection Agency, Report EPA-650/4-74-0056, Quality Assurance and Environmental Monitoring Laboratory, Research Triangle Park, N.C., February 1974.

42. Nader, J. S., F. Jaye, and W. Couner. Performance Specifications for Stationary-Source Monitoring Systems for Gases and Visible Emissions. U.S. Environmental Protection Agency, National Environmental Research Center, Research Triangle Park, N.C. Publication Number EPA-650/2-74-013. January 1974.

43. Devorkin, H. R. L. Chass, and A. P. Fudurich. Air Pollution Source Testing Manual. Los Angeles Air Pollution Control District. 1972.

44. Schulte, K. A., D. J. Larsen, R. W. Harnung, and J. V. Crable. Report on Analytical Methods Used in Coke Oven Effluent Study. Report No. NIOSH-74-105. National Institute of Occupational Safety and Health, Cincinnati, Ohio. May 1974.

45. Crable, J. B. and D. G. Taylor. NIOSH Manual of Analytical Methods. Report No. NIOSH-75-121. National Institute of Occupational Safety and Health, Cincinnati, Ohio. 1974.

46. Quality Assurance Handbook for Air Pollution Measurement Systems. Volume I, Principles. U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Quality Assurance Branch, Research Triangle Park, N.C. 27711.

47. Handbook for Quality Control in Water and Wastewater Laboratories. Analytical Quality Control Laboratory, National Environmental Research Center, Cincinnati, Ohio. June 1972.

48. Smith, F., and A. G. Nelson, Jr. Guidelines for Development of Quality Assurance Programs and Procedures. Final Report. Environmental Protection Agency, Durham, N.C. Contract Number EPA 68-02-0598. August 1973.

49. Precision Measurement and Calibration. In: National Bureau of Standards Handbook 77. Three Volumes, 1971. National Bureau of Standards, U. S. Government Printing Office, Washington, D. C.

APPENDIX B

DISPERSION MODELS

INTRODUCTION

Section V discussed the manner in which certain emission and site characteristics could be used in estimating the environmental sphere of influence associated with energy system development and operation. The role which dispersion models played in this task was briefly discussed. This Appendix discusses some of the models available for these analyses. In this discussion, for the most part, models for air, water, and land sectors are dealt with separately. However, a unified approach in which transport processes in all sectors have been incorporated into a single model is also discussed. Finally, an example is presented in which a modeling approach is used in one aspect of an environmental assessment.

ATMOSPHERIC TRANSPORT MODELS

Most atmospheric transport models fall into one of two categories. The first type of model is based upon the steady state gaussian plume approach in which emissions from a point or area source may be analytically related to concentrations at downwind receptor points. The second type of model of atmospheric transport involves a numerical solution of the equations of turbulent diffusion over a system of grid cells. Both the steady state and grid model may be modified to include plume rise, boundary layer effects, chemical transformation, and deposition. Some of the underlying concepts behind both steady state and grid modeling are discussed and some of the common models currently in use are briefly described.

Basic Concepts and Formulations

Steady State Model - The basic expression for the evaluation of steady state pollutant concentrations downwind of a point source is the gaussian plume equation.[1,2]

$$\chi_i(x,y,z)= \frac{Q_i(x)\exp\left(\frac{-y^2}{2\sigma_y^{\,2}(x)}\right)}{2\pi\,\sigma_y(x)\,\sigma_z(x)\,u}\left[\exp\left(-\frac{\left(z-h(x)\right)^2}{2\sigma_z^{\,2}(x)}\right)+\exp\left(-\frac{\left(z+h(x)\right)^2}{2\sigma_z^{\,2}(x)}\right)\right] \qquad (1)$$

where x = distance along plume axis (m)

y = horizontal distance from plume axis (m)

z = distance above surface (m)

$\chi_i(x,y,z)$ = concentration of pollutant i (g/m^3)

$Q_i(x)$ = effective emission rate of pollutant i for downwind distance x (g/sec)

$\sigma_y(x)$, $\sigma_z(x)$ = horizontal and vertical dispersion coefficients for a particular atmospheric stability (A,B,C,D,E,F)

u = wind speed at source height (m/sec)

$h(x)$ = effective emission height at distance x (m).

The variation of σ_y and σ_z with x for each of the six stability classifications (A to F) has been determined from a number of experiments[1] based upon low level releases of tracer material and does not strictly apply to elevated sources or downwind distances greater than about 5 km. The usual procedure, however, is to assume that these results are approximately true for greater source heights and that they may be extrapolated to longer distances. An example of the variation of σ_z with distance for stabilities A through F is given in Figure 21.[3] The choice of a given stability will depend upon wind speed, cloud cover, and sun elevation. The second exponential term in brackets on the right side of Equation (1) is an "image" point source contribution which is required to meet the zero flux boundary condition at the ground surface ($z = 0$). The effective

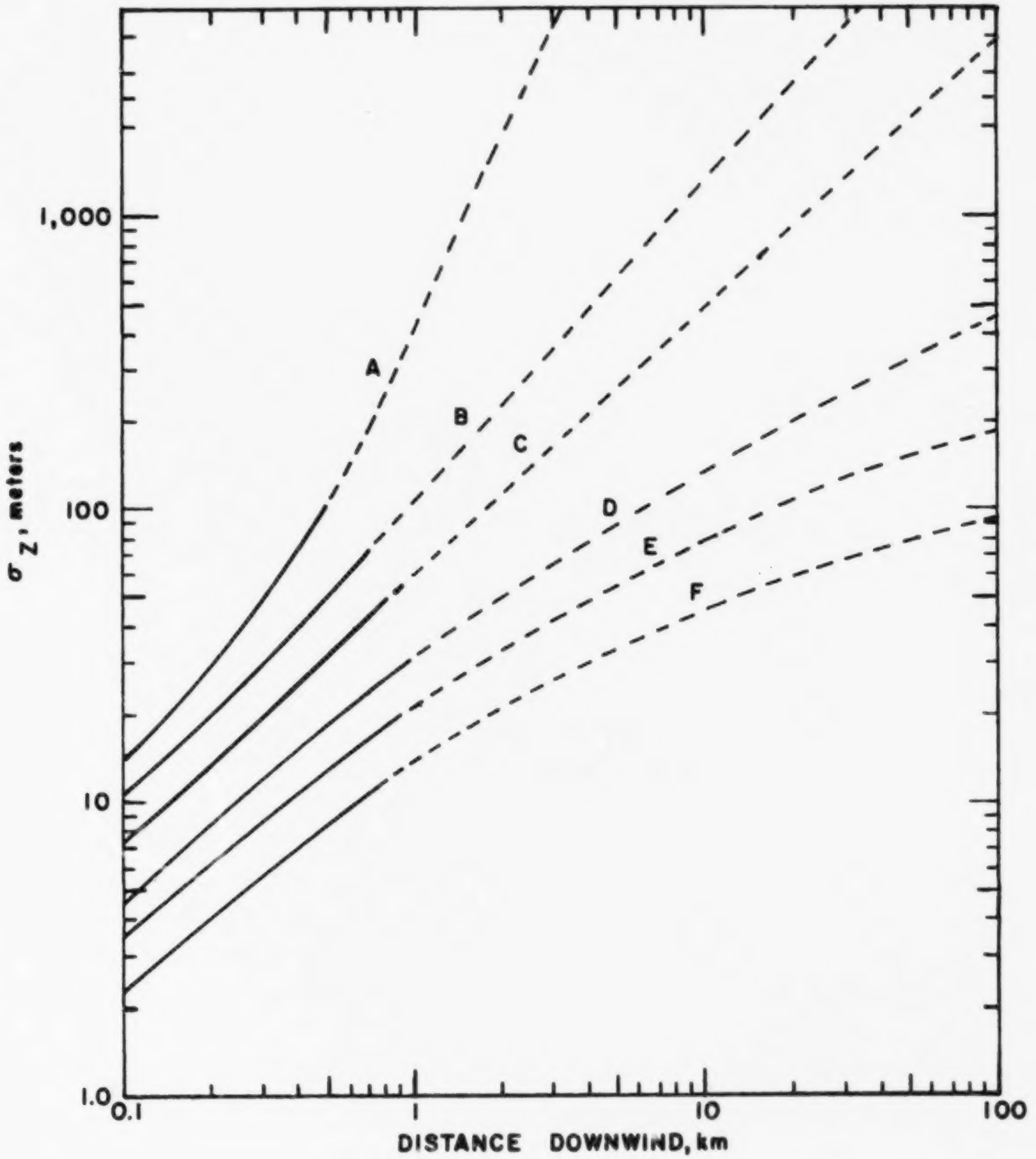


Figure 21. Vertical dispersion coefficient as a function of downwind distance from the source[3]

source strength $Q_i(x)$ will be different than the strength $Q_i(0)$ at the point of emission due to wet deposition, dry fallout, and chemical transformation. The effective stack height h(x) will be greater than the actual stack height h_o due to the buoyancy of the plume.[4] The expression for h(x) for stabilities A through D is given by

$$h(x) = h_o + \Delta h, \tag{2}$$

where $\Delta h = 1.6F^{1/3} u^{-1} x^{2/3}$ for $x \leq 3.5x^*$

$\Delta h = 1.6F^{1/3} u^{-1} (3.5x^*)^{2/3}$ for $x > 3.5x^*$

$x^* = 14F^{5/8}$ when $F < 55\ m^4/sec^3$

$x^* = 34F^{2/5}$ when $F \geq 55\ m^4/sec^3$

$F = gwr^2 \left(\frac{T_s - T_e}{T_e} \right)$

g = gravitational acceleration (m/sec^2)

w = stack gas ejection velocity (m/sec)

r = radius of stack (m)

T_s = stack gas temperature (°K)

T_e = air temperature (°K).

For stability classes E and F the plume rise becomes

$$\Delta h = 2.9 \left(\frac{F}{us} \right)^{1/3} \tag{3}$$

where $s = \frac{g}{T_e} \frac{d\theta}{dz}$

$\frac{d\theta}{dz} = 0.02$ °K/m for stability E

$\frac{d\theta}{dz} = 0.035$ °K/m for stability F.

The windspeed (u) at source height (h_o) may be related to the wind speed (u_m) measured at a standard distance (h_m) above ground level according to the following power law:[5]

$$u = u_m \left(\frac{h}{h_m} \right)^p \tag{4}$$

where the exponent (p) depends upon the stability class.

The presence of the mixing boundary may be accounted for by the incorporation of multiple image sources as was done to satisfy the zero flux condition at ground level.

In practice only several image terms need be taken since the contribution of additional terms will be negligible. For distances greater than $2\ x_L$, where x_L is given by $\sigma_z\ (x_L) = 0.47L$, Equation (1) may be approximated by

$$\chi_i(x,y,z) = \frac{Q_i\ (x)\ \exp\left(\frac{-\ y^2}{2\ \sigma_y^{\ 2}(x)} \right)}{\sqrt{2\pi}\ \sigma_y(x)\ u\ L} \qquad x > 2\ x_L \tag{5}$$

where L = depth of the mixing layer (m).

The first step in the determination of the effective source strength $Q_i(x)$ is the calculation of the deposition rate ω_i (x,y) which may be evaluated in the following manner:

$$\omega_i(x,y) = v_i\ \chi_i(x,y,0) + \Lambda_i \int_0^L \chi_i(x,y,z)\ dz \tag{6}$$

where ω_i (x,y) = deposition rate of pollutant i ($gm/m^2/sec$)
v_i = deposition velocity of pollutant i (m/sec)
Λ_i = washout coefficient of pollutant i (sec^{-1}).

The depletion of the source strength Q(x) per unit distance is then given by

$$\frac{\partial Q_i(x)}{\partial x} = -\int_{-\infty}^{\infty} \omega_i\,(x,y)\,dy \tag{7}$$

Solving for $Q_i(x)$ the following expression is obtained:[6]

$$Q_i(x) = Q_i(0) \quad \exp\left(-\int_o^x \beta_i(x')dx'\right) \tag{8}$$

$$\text{where} \quad \beta_i(x) = \left(\frac{2}{\pi}\right)^{1/2} \frac{v_i}{u\sigma_z(x)} \exp\left(-\frac{h^2(x)}{2\sigma_z{}^2(x)}\right) + \frac{\Lambda i}{u} \tag{9}$$

The expressions developed during the preceding discussions are only applicable to steady state conditions under which the average values of the meteorological variables will remain constant in time. This means that the gaussian plume approach is only realistic for periods of several hours. For intervals larger than these, parameters such as windspeed, stability, plume rise, and mixing height can be expected to change to a significant degree especially during the morning and evening hours. In addition, there is no provision within the framework of the model for treating variations in topography except, possibly, by adjusting the effective stack height for each receptor site to account for difference in elevation between source and receptor locations.

Numerical Models - The gaussian plume model we have just discussed is only an approximate solution of the more general material balance equation:[7]

$$\frac{\partial \chi_i}{\partial t} + \sum_{j=1}^{3} \frac{\partial}{\partial x_j} (u_j \chi_1) = \sum_{j=1}^{3} D_i \frac{\partial^2 \chi_i}{\partial x_j^2} + R_i (\chi_1, \chi_2, \ldots \chi_N) + S_i (x_1, x_2, x_3, t) \tag{10}$$

where χ_i = concentration of i^{th} species (g/m^3)
u_j = j^{th} component of the windspeed (m/sec)
D_i = molecular diffusivity of the i^{th} species (m^2/sec) (may be ignored for most applications)
R_i = production rate of i^{th} species due to chemical reactions (g/sec)
S_i = source term for i^{th} species at (x_1, x_2, x_3) (g/sec)
t = time (sec).

By separation of the concentrations (χ_i) and windspeeds (u_j) into average ($<\chi_i>$, $<u_j>$) and stochastic components (χ_i', u_j'), and by assuming that the term $<u_j' \chi_i'>$ can be linearly related to the gradient of the average concentration, the equation of turbulent diffusion is obtained:

$$\frac{\partial <\chi_i>}{\partial t} + \sum_{j=1}^{3} <u_j> \frac{\partial <\chi_i>}{\partial x_j} = \sum_{j=1}^{3} \sum_{k=1}^{3} \frac{\partial}{\partial x_j} \left(K_{jk} \frac{\partial <\chi_i>}{\partial x_k} \right) + R_i \left(<\chi_1>, \ldots, <\chi_N> \right) + S_i (x_1, x_2, x_3, t) \tag{11}$$

where K_{jk} = eddy diffusivity tensor (m^2/sec).

The expression given by Equation (1) represents the steady state solution to Equation (11).

Basically the numerical methods for solving Equation (11) fall into two categories. The first technique requires that a parcel of air be followed along a calculated trajectory for which time-dependent emissions are specified. In solutions of this type the lateral eddy diffusion is ignored so that the transport problem requires a solution to the diffusion equation in the vertical dimension only. Although this scheme is relatively simple, it allows the air quality to be predicted only along certain trajectories. The fixed coordinate solution to the transport-kinetics problem will give a determination of air quality over the entire urban area at a particular instant of time, but requires large amounts of computer storage and time.

The advection term $\langle u_j \rangle \dfrac{\partial \langle \chi_i \rangle}{\partial x_j}$ which was eliminated in the trajectory method, may result in "numerical diffusion" for long simulation times due to truncation errors in the finite difference procedure. There is also a difficulty in specifying realistic initial grid concentrations and boundary conditions.

Both the trajectory and grid models are primarily employed in the analysis of pollutant transport within an urban area, but could also be applied to an industrial complex surrounding a new or proposed energy system. For monitor siting application, the gaussian models would probably be sufficient unless a complex chemical kinetics scheme had to be incorporated.

Description of Atmospheric Transport Models of Interest

The most commonly applied atmospheric transport models, especially the gaussian plume variety, differ mainly in certain bookkeeping aspects such as the ability to handle different source-receptor configurations or concentration averaging times. As an example of the wide range of gaussian models available for different applications we shall consider the EPA UNAMAP[8] system.

The User Network for Applied Modeling of Air Pollution (UNAMAP) is a collection of models which cover a wide range of source types, source configurations, and averaging times. The basis for each of the models is a steady state gaussian plume approach augmented by treatment of other variables such as plume rise and mixing depth. The following models are available in the UNAMAP system.

- APRAC-1a[9] - The APRAC-1a model will compute hourly concentrations of CO, based upon both vehicular travel on primary and secondary traffic links and meteorological input data for windspeed, wind direction, and cloud cover. The program employs the standard gaussian plume formulation with concentrations becoming uniform in the vertical direction at a given distance downwind from the source due to the presence of an inversion layer. The depth of the mixing layer is obtained from temperature sounding carried out twice a day. There is provision in the model for an emissions adjustment due to various average vehicle speeds on different road types. The program also has the capability of considering the effect of buildings upon street level concentrations of CO.
- HIWAY[10] - This model calculates short-term CO concentrations in the vicinity of a roadway by means of a line integration of the gaussian plume formula using emission rates for several different lanes of traffic. Other inputs to the program include roadway and receptor coordinates and hourly wind speeds and stabilities.
- CDM[5] - The Climatological Dispersion Model calculates long-term average ground level air concentrations for one or two pollutants emitted from an array of point and area sources. Area source emissions are given as g/sec for a grid square of known size and effective emission height above the ground. For point sources the effective source height is calculated in terms of the actual stack height, stack diameter, gas exit velocity, and temperature (for both the stack gas and the ambient air).

The basic meteorological input to the CDM is a joint frequency function ϕ (k, l, m) which gives the joint frequency of occurrence of a wind direction, k, windspeed class, l, and a stability index, m. The model requires 16 wind directions, 6 windspeed classes, and 6 stability classes.

The orientations and distances of the point and area sources with respect to the receptors of interest are computed from source and receptor coordinates. The area sources must be broken down into a number of smaller elements for integration. The actual calculation of ground level air concentration is based upon a gaussian plume formulation in which the vertical dispersion coefficient is chosen to vary with distance from the source according to a power law with a different set of parameters for each atmospheric stability. The increase of windspeed with height above the ground is also accounted for by a stability dependent power law profile. The presence of the mixing layer is important at rather large distances from the source where it results in uniform distribution of a pollutant in the vertical direction.

- PTMAX - This model will calculate the maximum plume centerline concentration due to emissions from an elevated point source for a given set of windspeed, atmospheric stability, and plume rise parameters. The model also calculates the distance to the maximum concentration and the effective source height at this distance.

- PTDIS - A more detailed picture of concentrations downwind from a point source may be obtained by use of the program PTDIS. For a given windspeed, mixing height, emission strength, and stack parameters, ground level air concentration isopleths are determined within an angular sector to which the plume is confined.

- PTMTP - This program is quite similar to the CDM in many respects except that it does not include area sources and requires hourly input of wind direction, windspeed and atmospheric stability class rather than an annual frequency distribution of these quantities. The code has the additional feature of being able to account for varying receptor heights by reducing the effective source heights by the difference in elevation between

> the receptor and the base of the stack in question. The option is also available for printing out the individual contribution of each point source to the total concentration calculated for each receptor.

In addition to the gaussian models just discussed there are also models[11,12] available for the prediction of wet and dry deposition in a water shed system. Models similar to those of the UNAMAP system have been developed by the Tennessee Valley Authority (TVA)[13] for application to power plants during special meteorological conditions such as trapping and inversion breakup.

At the present time there is no widely accepted modeling technique for the prediction of long range transport of pollutants such as sulfates, but work is currently in progress toward that objective. One such model currently being applied and tested is a regional-continental scale transport, diffusion, and deposition model[14] recently developed by the Air Resources Laboratories (ARL). This long range transport model consists of two submodels, the first of which calculates air parcel trajectories while the second determines pollutant concentrations and deposition rates.

The basic input to the trajectory generation program consists of pilot balloon observations of wind speed, wind direction, height, and pressure for standard and significant levels. The wind vector used in the trajectory calculation is based upon an average of wind velocity through the transport layer weighted by the height of the observation above the bottom of the layer. The bottom of the transport layer is considered to be 300 meters above the average terrain elevation to eliminate the influence of surface frictional effects, which may cause the average transport speed to be underestimated. The terrain elevations used in the model are obtained from data tapes[15] giving the average terrain elevations for each 1-degree square over the world. The top of the transport layer is approximated by the average seasonal depth of the afternoon mixing layer[16] for the area in question. Data from several upper air stations is further weighted according to functions of the distance from the segment origin to the measurement site and the angle between the site wind vector and the line joining the segment origin and the measurement site. A number of sample trajectories generated in this manner are shown in Figure 22.[14] Ground level air concentrations along the trajectory are given by:

$$\chi = \frac{Q}{\pi \sigma_y \sigma_z \overline{u}} \exp \frac{-y^2}{2 \sigma_y^2} \tag{12}$$

where χ = ground level air concentration (g/m^3)

Q = emission rate (g/sec)

σ_y = cross wind standard deviation of the plume concentration distribution (m)

σ_z = vertical standard deviation of the plume concentration distribution (m)

$\overline{u}$ = mean wind speed along the trajectory (m/sec)

y = cross wind distance from trajectory segment (m).

To apply the climatological model, a large number of trajectories, starting at a given source point, are generated at specific time intervals (e.g., 4 hours) for the averaging period of interest (monthly, seasonally, annually). Trajectories are printed on a gridded map, with grid spacing and area coverage selected by the user. Ground level air concentration and deposition amounts are calculated for each grid box along and normal to each trajectory segment. The calculation normal to the trajectory is terminated at the 4 σ_y distance. Calculated concentrations from all trajectories are accumulated in each grid box and averaged over the chosen time period.

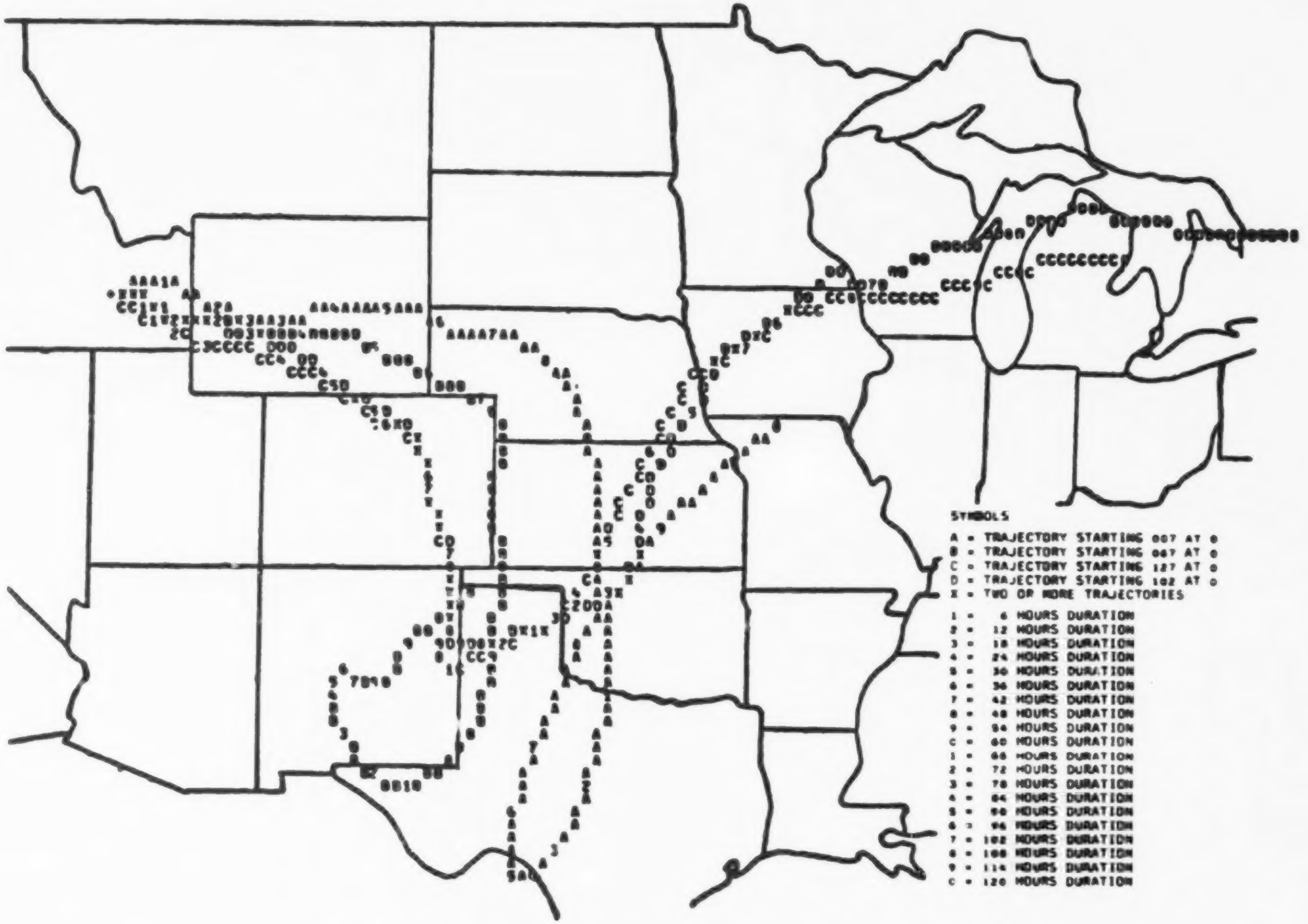


Figure 22. Series of trajectories generated by the ARL model[14]

Pollutant Transport Models for Water

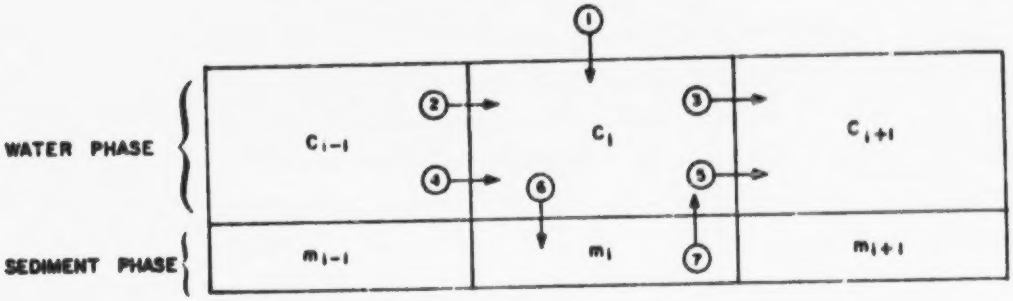
Mathematical models for pollutant transport in an aqueous system are similar in some respects to the atmospheric models just discussed. In each case the mathematical formulation must account for phenomena such as advection, diffusion, and chemical transformation. A transport model for water, however, must be tailored according to the physical and geometrical characteristics of the particular body of water under study. In spite of this drawback some of the more common features of the water transport models can be understood by considering in some detail an example calculation. A model was chosen which was originally designed to predict the transport of radionuclides in a stream system,[17] but could just as easily be applied to the transport of other types of pollutants.

The mathematical description of pollutant transport is based upon a mass-balance equation for a segment of the stream including the associated bottom sediments. A vegetative sorption-desorption process could be incorporated into the model in much the same manner as were the bottom sediments. The material balance for the stream and sediment is shown in Figure 23. In the limit of Δx the balance equations given in Figure 23 reduce to the following two expressions:

$$\frac{\partial C}{\partial t} = D_x \frac{\partial^2 C}{\partial_x{}^2} - U \frac{\partial C}{\partial x} + \frac{k_1}{Ha} (m - K_s C) \qquad (13)$$

$$\frac{\partial m}{\partial t} = k_1 (K_s C - m) \qquad (14)$$

Values for k_1 and K_s may be estimated from the results of laboratory adsorption-desorption experiments using actual stream bed materials. The diffusivity D_x and flow velocity U can be taken from field observations. For most flow regimes of interest D_x has a power law dependence upon the flow velocity.



Material balance for the water phase

① + ② - ③ + ④ - ⑤ - ⑥ + ⑦ = $\frac{\Delta C_i}{\Delta t}$

① = Q (emission rate)

② = $U\ C_{i-1}$ (advection rate into cell i, u = stream velocity)

③ = $U\ C_i$ (advection rate out of cell i)

④ = $D_x \frac{(C_{i-1} - C_i)}{\Delta x}$ (diffusion into cell i, D_x = longitudinal diffusivity, Δx = cell spacing)

⑤ = $D_x \frac{(C_i - C_{i+1})}{\Delta x}$ (diffusion out of cell i)

⑥ = $\frac{k_1\ K_s\ C_i\ \Delta_x}{Ha}$ (adsorption in bottom sediments, k_1 = reaction rate k_s = distribution coefficient, H = stream depth, a = cross sectional area of the core sample)

⑦ = $\frac{k_1\ m_i\ \Delta x}{Ha}$ (desorption from bottom sediments, m = quantity of substance in the soil core)

Material balance for the sediment phase

⑥ - ⑦ = $\frac{\Delta m_i}{\Delta t}$

⑥ = $k_1\ K_s\ C_i$

⑦ = $k_1\ m_i$

Figure 23. Pollutant material balance for water and sediment phases of a stream

A general solution of Equations (13) and (14), which allows for nonuniform stream characteristics, may be obtained through a finite difference procedure. The results of one such concentration calculation at downstream water sampling stations as a function of time is shown in Figure 24 for a finite pollutant release time. The most obvious feature seen in these curves is increasing width at greater distances downstream due to the effect of longitudinal turbulent diffusivity. The bottom sediments have a capacitive function in that they retain adsorbed pollutants which are then slowly released to the water after the passage of the main water concentration peak.

Modeling Pollutant Transport in Soils

To illustrate the application of a mathematical model for the prediction of pollutant transport in the soil, an analytical technique can be used which was developed by J.J. Jurinak[18] and co-workers for EPA to simulate cation transport in saturated soils. While this particular model is only one example of a pollutant transport calculation for the soil, the general procedures apply to most other similar models. Repeated runs of this model could be carried out to determine the variation of pollutant migration rates within the soil as a function of various soil characteristics such as pore velocity and dispersion coefficient.

By considering the mass balance for a cation such as Ca^{+2} within an element of soil of depth dz, the following expression may be derived which relates the amount of cation in aqueous solution to that adsorbed on the soil particles:

$$D_o \frac{\partial^2 C}{\partial z^2} - V_o \frac{\partial C}{\partial z} = \frac{\partial C}{\partial t} + \frac{\rho}{\varepsilon} \frac{\partial q}{\partial t} \qquad (15)$$

where D_o = dispersion coefficient

V_o = pore velocity

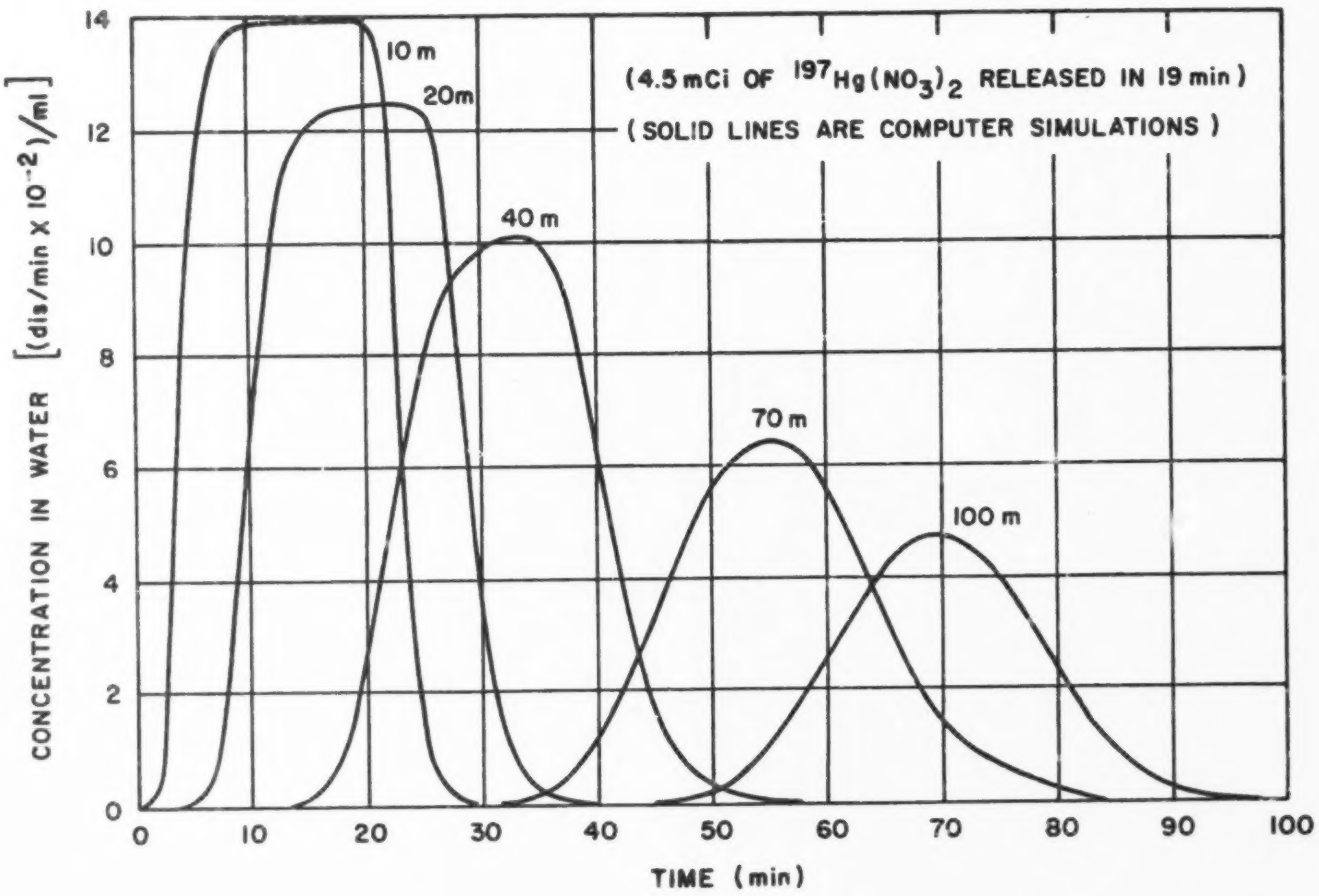


Figure 24. Computer simulation of mercury transport during a stream tagging experiment; data taken at 10, 20, 40, 70, and 100 meters downstream from injection point

ρ = bulk density

ε = pore fraction

q = amount of material adsorbed

C = concentration of material in solution.

The concentrations in the solid and liquid phases, q and C, may be nondimensionalized by dividing by the cation absorption capacity (Q) and the initial total concentration in solution (C_o):

$$X = \frac{C}{C_o} \tag{16}$$

$$Y = \frac{q}{Q} \tag{17}$$

These nondimensionalized concentrations are usually related to one another through an adsorption function or adsorption isotherm:

$$Y = f(X) \tag{18}$$

With the transformations indicated in Equations (16) through (18) the material balance equation given by Equation (15) may be rewritten as follows:

$$D\ (X)\ \frac{\partial^2 X}{\partial_z{}^2} - V\ (X)\ \frac{\partial X}{\partial z} = \frac{\partial X}{\partial t} \tag{19}$$

where

$$D(X) = \frac{Do}{1 + \frac{\rho Q}{\varepsilon Co}\frac{dY}{dX}} \tag{20}$$

$$V(X) = \frac{Vo}{1 + \frac{\rho Q}{\varepsilon Co}\frac{dY}{dX}} \tag{21}$$

Equation (19) may be solved by a finite difference procedure by application of the following boundary conditions:

$$X\ (z,0) = 0 \qquad 0 \leq z \leq L \qquad (22)$$

$$X\ (X_o,t) = 1.0 \qquad t > 0 \qquad (23)$$

$$\frac{\partial X}{\partial z}\ (L,t) = 0 \qquad t > 0 \qquad (24)$$

where L is the length of the soil column under study.

The results of one of these calculations are shown in Figure 25 which illustrates a number of different concentration profiles with depth as a function of time.

An analysis of ion exchange processes in unsaturated soil is more complicated because the flow of water itself through the soil must be determined in addition to the sorption-desorption. A complete solution for flow through porous media will require an equation of continuity of the fluid, an equation of continuity of the solid, an equation of motion of the fluid, a consolidation equation for the medium, and an equation of state for the compressibility of water. Because a detailed exposition of this technique is beyond the scope of this document, the reader is referred to a number of references on the subject.[19,20,21,22]

Models for Heat Transport

Waste heat may be released to the atmosphere by means of cooling towers or by direct discharge of cooling water into a nearby body of water. Other cooling systems include artificial cooling lakes, floating spray devices and dry cooling towers. A large fraction of the heat released to the atmosphere by cooling towers is in the form of latent heat which is released once condensation occurs. Aside from some rather local

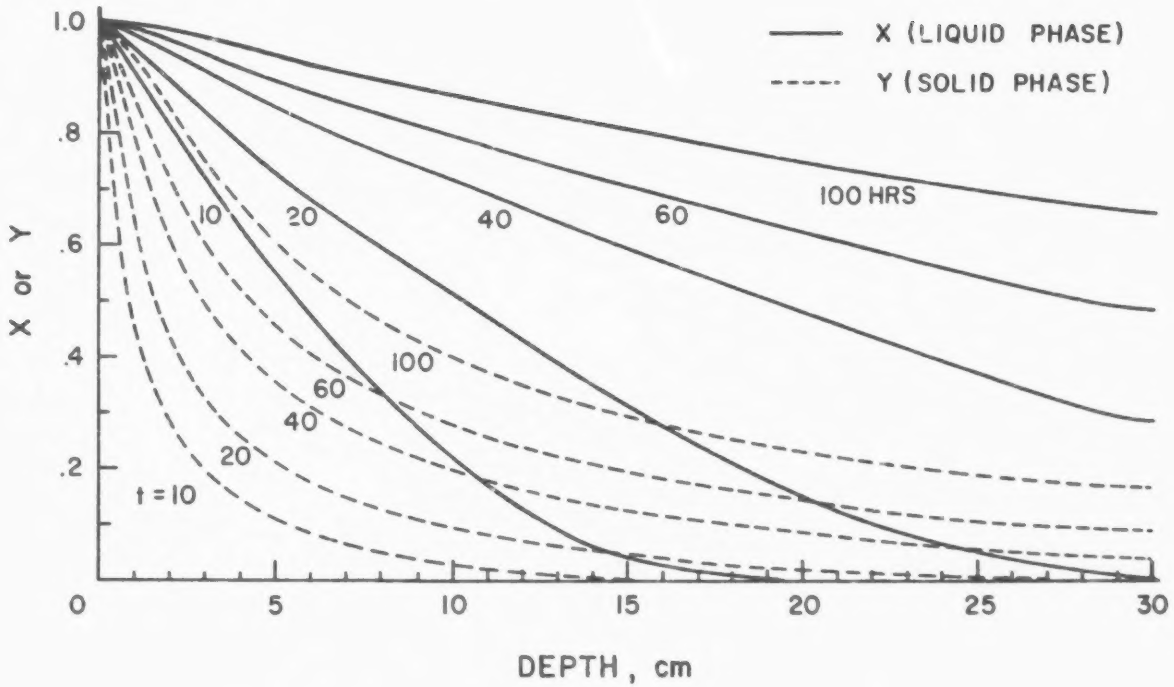


Figure 25. The cation concentration profiles X(z,t) and Y(z,t) in liquid and solid phases[13]

weather modification effects associated with artificially generated precipitation, the primary impacts of cooling tower operation are consumptive water loss and the temporary reduction in visibility due to downwash of the condensing plume. Techniques for calculation of plume rise from cooling towers are similar to those mentioned earlier in connection with the gaussian plume models for atmospheric pollutant dispersion, except that for saturated plumes the latent heat of vaporization must enter into the buoyancy calculation.[23,24,25] Variables such as temperature, potential temperature gradient, specific humidity profile, and initial flux of buoyancy can be used to arrive at estimates of heights above the ground for plume condensation.

The disposal of waste heat to a water system can be carried out in a number of different ways. One method is simply to discharge cooling water to the surface of a river or lake to maximize the transfer of heat to the atmosphere. Due to water quality standards requiring a considerable dilution of incoming heated water within a given distance from the point of discharge, this surface disposal technique is being abandoned in favor of a system of submerged diffuser nozzles, a method long employed for the dilution of municipal sewage. Buoyant jets of hot water which rise from each of the diffusers become rapidly mixed with ambient water in a manner similar to that which occurs during the rise of a hot plume emitted from a stack. The effectiveness of such a procedure will depend upon physical parameters such as injection velocity, water depth, nozzle diameter, nozzle spacing, and stream velocity. A numerical simulation of this process is a sizable undertaking which should be carried out in parallel with a laboratory or field program to aid in model validation. In spite of the complexity of this subject, there are a number of references[26,27,28,29] which can provide a general understanding of the modeling procedures.

Unified Approach to Transport Modeling

Up to this point we have examined modeling techniques specific to individual sectors of the environment such as air, water, and land. Recently several efforts have been underway to develop a unified modeling approach to the analysis of pollutant transport. A model of this type is currently in its final stages of development under National Science Foundation sponsorship.[30] The original motivation behind the development of this technique was the desire to have a comprehensive analytical procedure to follow the movement of trace metals such as cadmium and lead through the various sectors of the environment, but the model could just as easily be applied to the transport analysis of pollutants associated with the different phases of energy system development.

The model is basically a merger of an adaptation of the Stanford Watershed Model[31] and an atmospheric transport and deposition submodel similar to those discussed earlier in this appendix. The Stanford Watershed Model apportions different amounts of incoming precipitation to various compartments of a watershed system according to the soil and vegetative characteristics of the area and the current moisture content of the various compartments. In heavily forested regions, rainfall incident upon a watershed is subject to detention, storage and evaporation. Moisture reaching the ground surface may either percolate into the soil and groundwater compartments or move laterally toward a stream as overland flow or interflow through the top layer of saturated soil. Loss of water through transpiration is also provided for in the calculation scheme. The flow rate for water once it reaches the stream channel is taken to be a function of the channel depth, geometry, and roughness. The Stanford Watershed Model was generalized by D.D. Huff[32] to handle the transport of trace constituents through a watershed in addition to the actual flow of water itself. This adaptation, known as the Wisconsin Hydrologic Transport Model, accepts trace element inputs in the form of both dry and wet deposition rates. The transport of these trace elements through the soil is mathematically simulated in terms of theoretical soil plate thicknesses and an equilibrium distribution coefficient which determines the fraction of each constituent in solution and the fraction adsorbed on soil particle surfaces. The amount of soil erosion on exposed surfaces adjacent to a stream is calculated for each rainfall event, thereby giving the rate of trace substance input to the stream for that fraction adsorbed in the exposed top soil layer. The most recent modification to this model has been the incorporation of an atmospheric transport submodel for the prediction of wet and dry deposition rates based upon emissions from a collection of point, area, and fugitive sources in the vicinity. Other improvements to the model included a technique for handling sediment transport and ion exchange in the stream system, a more realistic mechanism for the calculation of moisture and solute transport within the soil, and a method for calculation of pollutant dispersal resulting from direct injection of effluent into the stream channel.

A unified modeling approach similar to the one we have just described could, in principle, aid in the siting and operation of ambient concentration monitors, particularly with respect to the range and rate of the various transport processes. The basic difficulties in the application of this technique are the extensive input requirements of the component submodels. Since a survey of environmental characteristics affecting pollutant transport has been proposed (Section V) as an early step in the impact evaluation procedure, only a minor amount of additional work would be necessary to quantify these characteristics in a format compatible with the input requirements of the unified model.

Example Model Application

To illustrate the role of modeling in an environmental assessment, an example of how a model may be used to estimate pollutant concentration levels within one sector of the environment is presented. Determination of the accumulation of trace metals in the soil due to fly ash emissions from a coal-fired power plant is the objective. The expression for the deposition rate given by Equation (6) may be generalized in the following manner to describe an average annual deposition rate over a 22 1/2-degree arc at a distance x from the power plant:

$$\omega(x,\theta) = \sum_{p=1}^{Ms} \sum_{r=1}^{Mw} \frac{F_{pr}(\theta)}{\sigma_p(x) U_r x} \left\{ 2.453 \Lambda W_w Q_{pr}(x) \sigma_p(x) + 2.032 v W_f \exp\left[\frac{-h^2}{2\sigma_p^{2}(x)}\right] Q_{pr}^{f} \right\} \tag{25}$$

$$Q_{pr}^{w} = Q_o \exp\left[- \frac{x}{U_r} - \frac{v}{U_r} g_p(x)\right] \tag{26}$$

$$Q_{pr}^{f} = Q_o \exp\left[- \frac{v}{U_r} g_p(x)\right] \tag{27}$$

$$g_p(x) = \left(\frac{2}{\pi}\right)^{1/2} \int_o^x dx' \exp\left[\frac{-h^2}{2\sigma_p^{2}(x')}\right] \bigg/ \sigma_p(x') \tag{28}$$

where $F_{pr}(\theta)$ = fraction of time during which the wind blows from direction sector θ, with wind speed class r, and stability class p

$\omega(x,\theta)$ = deposition rate (g/m^2/sec) in direction θ^{v}, (1 to 16) at a distance x from the source

W_w = washout weight (fraction of time both washout and fallout are occurring)

W_f = fallout weight (fraction of time in which only fallout occurs)

v = deposition velocity (m/sec)

Λ = washout coefficient (sec^{-1})

Q_o = emission rate measured at the source (g/sec).

The y-dependence has been removed from Equation (25) by distributing the integrated concentration in the y direction uniformly over a 22 1/2-degree arc. Tabulations of $F_{pr}(\theta)$ may be obtained from the National Climatic Center, Ashville, North Carolina. A 14-year deposition pattern, calculated by use of these relationships, is shown in Figure 26, along with the model inputs[33] used in the calculation.

Assuming that the deposited fly ash is uniformly mixed to a given depth within the soil, the following relationship exists between trace metal concentrations in the fly ash and in the soil:

$$C_x = \frac{C_f M_f + C_i M_s}{M_f + M_s} \tag{29}$$

where C_x = concentration in the soil doped with fly ash

C_f = concentration in the fly ash

C_i = initial concentration in the soil

M_f = mass of fly ash

M_s = mass of soil.

Equation (29) may be rewritten as:

$$\frac{C_x}{C_i} = \frac{\frac{C_f}{C_i} + \frac{M_s}{M_f}}{1 + \frac{M_s}{M_f}} \tag{30}$$

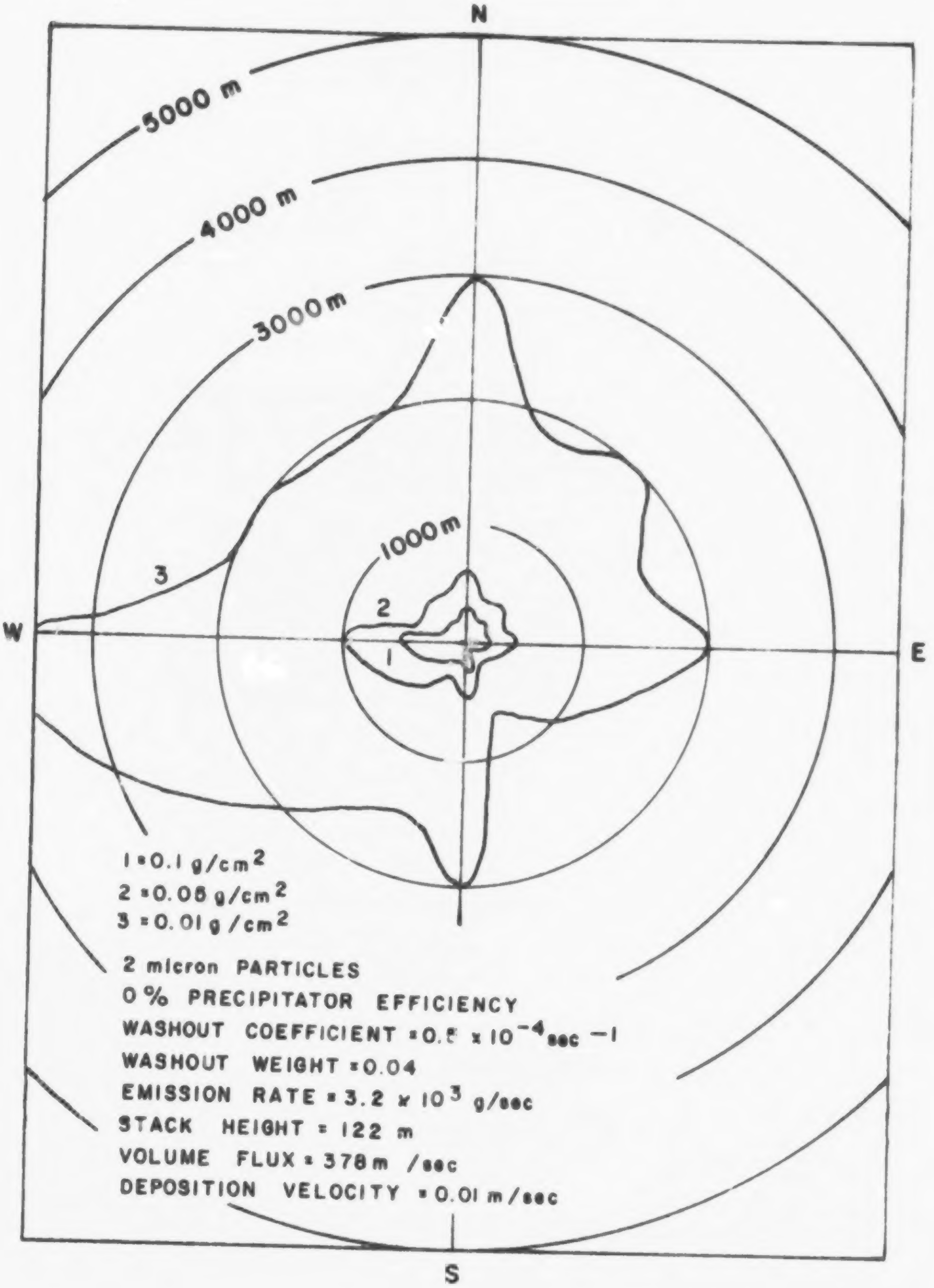


Figure 26. Calculated 14-year fly ash deposition pattern in the vicinity of a coal-fired power plant[26]

which relates the trace metal enrichment factor in fly ash $\frac{C_f}{C_i}$ to the enrichment factor in the contaminated soil. In Table 12, we have calculated these enrichment factors for a number of different soil mixing depths assuming an integrated deposition of 0.01 g/cm^2 and a density of soil of 2.5 g/cm^3. Based upon this calculation, a considerable enrichment (at least 2 or 3 orders of magnitude) in the fly ash would be required before any real increase of concentration could be seen in the soil. The estimates given in Table 12 are actually high because they do not reflect the effect of erosion over the time period in question.

Table 12. CALCULATED CONCENTRATION RATIOS IN SOIL CORRESPONDING TO 0.01 g/cm^2 TOTAL FLY ASH FALLOUT

1 cm		3 cm		10 cm	
$\frac{M_f}{M_s} = 0.004$		$\frac{M_f}{M_s} = 0.00133$		$\frac{M_f}{M_s} = 0.0004$	
$\frac{C_f}{C_i}$	$\frac{C_x}{C_i}$	$\frac{C_f}{C_i}$	$\frac{C_x}{C_i}$	$\frac{C_f}{C_i}$	$\frac{C_x}{C_i}$
1	1	1	1	1	1
5	1.02	5	1.01	5	1.00
10	1.04	10	1.01	10	1.00
100	1.39	100	1.13	100	1.04
1000	4.98	1000	2.33	1000	1.40

REFERENCES

1. Pasquill, F. Atmospheric Diffusion. London, D. Van Nostrand Company, Ltd. 1962.

2. Gifford, F. A., Jr. An Outline of Theories of Diffusion in the Lower Layers of the Atmosphere. In: Meteorology and Atomic Energy 1968, Chapter 3. D. Slade (ed.). United States Atomic Energy Commission.

3. Turner, D. B. Workbook of Atmospheric Dispersion Estimates. U.S. Department of Health, Education and Welfare, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration, Cincinnati, Ohio. Public Health Service Publication No. 999-AP-26. Revised, 1969.

4. Briggs, G. A. Plume Rise. AEC Critical Review Series. United States Atomic Energy Commission. Report No. TID-25075. 1969.

5. Busse, A. D. and J. R. Zimmerman. User's Guide for the Climatological Dispersion Model. U.S. Environmental Protection Agency, Raleigh, N. C. Publication No. EPA R-4-73-024. December 1973.

6. Van der Hoven, I. Deposition of Particles and Gases. In: Meteorology and Atomic Energy. 1968. p. 202-207.

7. Seinfeld, J. H., S. D. Reynolds, and P. M. Roth. Simulation of Urban Air Pollution. Photochemical Smog and Ozone Reactions, Advances in Chemistry Series, 113. American Chemical Society, Washington, D. C. 1972.

8. A tape containing the UNAMAP programs and test data may be obtained from the National Technical Information Service. U.S. Department of Commerce, Springfield, Virginia 22151. NTIS Accession No. PB 229771. 1974.

9. Mancuso, R. L. and F. L. Ludwig. User's Manual for the APRAC-1a Urban Diffusion Model Computer Program. Stanford Research Institute, Menlo Park, California. Contract No. CAPA-3-68(1-69). 1972. p. 119.

10. Zimmerman, J. R. and R. S. Thompson. User's Guide for HIWAY, A Highway Air Pollution Model. U.S. Environmental Protection Agency, Raleigh, N. C. Publication No. EPA-650/4-74-008. February 1975.

11. Hanna, S. R. Dry Deposition and Precipitation Scavenging in the ATDL Computer Model for Dispersion from Multiple Point and Area Sources. Box E, Oak Ridge, Tennessee. Atmospheric Trubulence and Diffusion Laboratory Report No. 71. 15 p.

12. Mills, M. T. and M. Reeves. A Multi-Source Atmospheric Transport Model for Deposition of Trace Contaminants. Computer Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830. ORNL-NSF-EATC-2. October 1973.

13. Carpenter, S. B., T. L. Montgomery, J. M. Leavitt, W. C. Colbaugh, and F. W. Thomas. Principal Plume Dispersion Models: TVA Power Plants. J Air Pollu Control Assoc. 21(8). August 1971.

14. Heffter, J. L., A. D. Taylor, and G. J. Ferber. A Regional-Continental Scale Transport, Diffusion, and Deposition Model. Air Resources Laboratories, Silver Springs, Maryland. NOAA Technical Memorandum ERL ARL-50. June 1975.

15. Smith, S. M., H. W. Menard, and G. Sharmin. World Wide Ocean Depth and Land Elevations Averaged for One Degree Squares of Latitude and Longitude. Scripps Institute of Oceanography, La Jolla, California. (Available from National Oceanic Data Center, Navy Yard Annex, Washington, D. C.). 1966.

16. Holzworth, G. C. Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States. U.S. Environmental Protection Agency, Office of Air Programs, Research Triangle Park, N. C. EPA Publication No. AP-101. January 1972.

17. Shih, C. S. and E. F. Gloyna. Radioactivity Transport in Water: Mathematical Model for the Transport of Radionuclides. Technical Report to the U.S. Atomic Energy Commission. Report No. EHE-04-6702, CRWR-18. 1967.

18. Jurinak, J. J., S. H. Lai, and J. J. Hassett. Cation Transport in Soils and Factors Affecting Soil Carbonate Solubility. U.S. Environmental Protection Agency. Publication No. EPA-R-2-73-235. May 1973.

19. Freeze, R. A. Three-dimensioned Transient, Saturated-Unsaturated Flow in a Ground-Water Basin. Water Resour Res. 7:2. 1971. p. 347.

20. Reeves, M. and J. O. Duguid. A Soil and Ground-Water Pollutant Transport Model. In: Proceedings of the First Annual NSF Trace Contaminants Conference. Oak Ridge National Laboratory, Oak Ridge, Tennessee. August 8-10, 1973. Publication No. CONF-730802. p. 266-272.

21. Dutt, G. R., M. J. Shaffer, and W. J. Moore. Computer Simulation Model of Dynamic Bio-Physio-Chemical Processes in Soils. Technical Bulletin No. 196. Agriculture Experimental Station, University of Arizona. October 1973.

22. Begovich, C. L. and D. R. Jackson. Documentation and Application of SCEHM, A Model for Soil Chemical Exchange of Heavy Metals. Oak Ridge National Laboratory, Oak Ridge, Tennessee. ORNL-NSF-EATC-16. October 1975.

23. Hanna, S. R. Rise and Condensation of Large Cooling Tower Plumes. Journal of Applied Meteorology. 11(5):793-799. 1972.

24. Csanady, G. T. Bent-Over Vapor Plumes. Journal of Applied Meteorology. 10:36-42. 1971.

25. Wigley, T. M. L. and P. R. Slawson. On the Condensation of Buoyant, Moist, Bent-Over Plumes. Journal of Applied Meteorology. 10:263-269. 1971.

26. Stolzenbach, K. D. and D. R. F. Harleman. Analytical and Experimental Investigation of Surface Discharges of Heated Water. U.S. Environmental Protection Agency. Publication No. 16130 DJU02/71. February 1971.

27. Koh, R. C. Y. and L. Fan. Mathematical Models for the Prediction of Temperature Distributions Resulting from the Discharge of Heated Water into Large Bodies of Water. U.S. Environmental Protection Agency. Publication No. 16130 DWO 10/70. October 1970.

28. Shirazi, M. A. and L. R. Davis. Workbook of Thermal Plume Prediction, Vol. 2, Surface Discharge. U.S. Environmental Protection Agency. Publication No. EPA-R2-72-005b. May 1974.

29. Trent, D. S. and J. R. Welty. Numerical Thermal Plume Model for Vertical Outfalls into Shallow Water. U.S. Environmental Protection Agency. Publication No. EPA-R2-73-162. March 1973.

30. Ecology and Analysis of Trace Contaminants. Progress Report. October 1973 to September 1974. Oak Ridge National Laboratory, Oak Ridge, Tennessee. ORNL-NSF-EATC-11. December 1974.

31. Crawford, N. H. and R. K. Linsley. Digital Simulation in Hydrology: Stanford Watershed Model IV. Stanford University Technical Report No. 39. 1966.

32. Huff, D. D. Simulation of the Hydrologic Transport of Radioactive Aerosols. PH.D. Thesis. Stanford University. 1968.

33. Trace Element Measurements at the Coal-Fired Allen Steam Plant. Progress Report. February 1973 to July 1973. Oak Ridge National Laboratory, Oak Ridge, Tennessee. September 1973.

APPENDIX C

DATA RETRIEVAL AND INFORMATION SYSTEMS APPLICABLE TO ENVIRONMENTAL ASSESSMENTS

INTRODUCTION

This Appendix is intended to provide the reader with a reference listing of available data retrieval and information systems pertaining to environmental quality and to environmental effects of potential energy system effluents. The majority of the information systems have been compiled by the federal government and include monitoring data, environmental literature, and results of research and development programs. Federal data handling and information systems are sponsored and operated by the U.S. Environmental Protection Agency, U.S. National Oceanic and Atmospheric Administration, U.S. Geological Survey, U.S. Department of the Interior, and others. Table 13 lists data handling system names, content, and sponsoring agency.

The systems outlined above are expanded in the remainder of the Appendix (Tables 14 through 19). The following detailed information is reported for each program:

- Name of System and Sponsor
- Brief Description
- Scope
- Input Data Sources
- Access to System
- Available User's Guide

Preceding page blank

- Form of Data Output
- Use Restrictions

The listing provides the reader with an introduction to the available information services. The user is given an overview of the type of information available and is provided with the means for further investigation and use of specific programs. In some cases it is not certain whether a particular system is on-line, revised, or obsolete; this type of information is noted in the tables when available.

A great deal of information at the state level is available from federal retrieval systems. State air and water quality data are stored in such systems as SAROAD and STORET in keeping with requirements of the Clean Air Act of 1970 and the Water Pollution Control Act of 1972. The states are required to monitor, compile, and analyze data on ambient air and water quality and submit this data to the EPA on a quarterly, semi-annual, or annual basis. These reporting systems provide the basis for operation of the EPA's more comprehensive information handling systems.

REFERENCES

The following references are useful in identifying data retrieval and information sources at the federal, regional, state, and local levels.

A. A Directory of Information Resources in the United States. Revised Edition. Science and Technology Division, National Referral Center. Library of Congress, Washington, D.C. 1974.

The National Referral Center functions as an intermediary, directing scientific and technical inquiries to organizations or individuals who have specialized knowledge. The document is a listing of information resources including professional societies, university research bureaus and institutes, federal and state agencies, industrial laboratories, museum specimen libraries, information and document centers, and abstracting and indexing services.

B. Encyclopedia of Information Systems and Services. Second International Edition. Published by Anthony T. Krozas Associates. 1974.

An international guide to information storage and retrieval systems, computerized data bases, SDI services, data base publishers, clearing houses and information centers, library and information networks, data collection and analysis centers, micrographic systems and services, and consulting, research, and coordinating agencies.

C. Environmental Information Systems Directory. U.S. Environmental Protection Agency, Office of Planning and Management, Office of Administration, Management Information and Data Systems Division. August 1973.

A listing of all information systems activities, both automated and manual, in the EPA. Information from the inventory is available to EPA and other federal organizations performing environment-related work.

D. Where to Find State Plans to Clean the Air. U.S. Environmental Protection Agency. U.S. Government Printing Office. Publication Number 732-581/439. 1974.

The Clean Air Act requires each state to develop plans to achieve and maintain the clean air standards set by the EPA to protect public health and welfare. The implementation plans contain state guidelines for reducing air pollution emissions to acceptable levels. Included are regulations and other administrative requirements that the state places on individual pollutant sources.

Each state is required to maintain an up-to-date version of its implementation plan in each air quality region.

This booklet is a list of locations, established by the States, where the files are kept for public review.

E. Bosch, John C., Jr. Aerometric and Emissions Reporting System. February 1975.

This recent document outlines the complete AEROS system sponsored by the Environmental Protection Agency. The purpose and scope of each subsystem is defined along with an explanation of the correlation between the specific subsystem and the overall AEROS program.

F. Environment Reporter. Bureau of National Affairs, Inc.,
1231 25th Street N.W., Washington, D.C. 20037.

A weekly review of pollution control and related environmental management problems.

Table 13. DATA HANDLING AND INFORMATION SYSTEMS AT THE FEDERAL LEVEL

Sponsor	Air	Water	Solid waste	Toxic substances	Noise	Comprehensive Environmental Data
U.S. Environmental Protection Agency	AEROS - Aerometric and Emissions Reporting Systems NEDS - National Emissions Data System SAROAD - Storage and Retrieval of Aerometric Data QAMIS - Quality of Aerometric Data SOTDAT - Source Test Data Storage HATREMS - Hazardous and Trace Substance Inventory System SIP - State Implementation Plan EDS - Energy Data System FPC-67 - Cumulative FPC Form 67 Data System APTIC - Air Pollution Technical Information Center UNAMAP - Users Network for Applied Modeling of Air Pollution	STORET - Storage and Retrieval of Water Quality Data ENVIRON - Environmental Information Retrieval On-Line GPSF - General Point Source File NEI - National Estuarine Inventory Water Quality Standards	SWIRS - Solid Waste Information Retrieval System		NOISE - Noise Information Retrieval System	NERC - National Environmental Research Center PRES - Program Review and Evaluation Environmental Impact Statement System
U.S. National Oceanic and Atmospheric Administration		ENDEX - Environmental Data Index EDS - Environmental Data Service				EBDB - Environmental Data Base Directory ESIC - Environmental Science Information Center
U.S. Geological Survey, Water Resources Division		OWDC - Office of Water Data Coordination NWDS - National Water Data System				
U.S. Department of the Interior		WRSIC - Water Resources Scientific Information Center Network				

Table 13 (continued). DATA HANDLING AND INFORMATION SYSTEMS AT THE FEDERAL LEVEL

Sponsor	Air	Water	Solid waste	Toxic substances	Noise	Comprehensive Environmental Data
Oak Ridge National Laboratory				EISO - Environmental Information System Office TMIC - Toxic Materials Information Center EMIC - Environmental Mutagen Information Center TIRC - Toxicology Information Response Center ESIC - Ecological Sciences Information Center		
U.S. Public Health Service				NIOSH - National Institute of Occupational Safety and Health, Technical Information Services Branch NIEHS - National Institute of Environmental Health Sciences - Information Services CHEMLINE - Chemical Dictionary On-Line TOXLINE - Toxicology Information Program (TIP)		
Battelle Memorial Institute				EIAC - Environmental Information Analysis Center EIC - Energy Information Center		
Council on Environmental Quality - CEQ				MERES - Matrix of Environmental Residuals for Energy Systems		
The Center for Short-Lived Phenomena. Cambridge Ma.				United Nations Environment Program		
Ecology Forum, Inc.				EIC - Environmental Information Center		
Pollution Abstracts, Inc.				Pollution Abstracts		

Table 14. FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - AIR

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
U.S. Environmental Protection Agency Air Pollution Office National Air Data Branch (NADB) NEDS SAROAD	Collection, analysis, and publication of emission and ambient air data by way of two computer systems: 1. NEDS - National Emissions Data System 2. SAROAD - Storage and Retrieval of Aerometric Data SAROAD contains national ambient air quality data, statistically analyzed and reduced from nationwide ambient monitoring systems. NEDS is comprised of emissions data from individual point and area sources.	Air pollution, air quality, and emissions data. NEDS - 75,000 point sources 3,500 area sources SAROAD - 3,000 air monitoring stations, 27 million entries to data base since 1958.	Data generated by EPA and its contractors, and collected from state and local agencies.	TSO and batch access systems are available in all 10 EPA regional offices, linked to central computer at Research Triangle Park, North Carolina.	**NEDS**: APTD-1135, "Guide for Compiling a Comprehensive Emission Inventory" Volume II of the AEROS manual. **SAROAD**: A complete directory of SAROAD site data published annually. Also refer to Volume III of the AEROS manual.	**NEDS**: Point and area source data can be arranged in multiple ways. The more common outputs are emissions according to pollutant, geographic area, source category, type ownership, specific fuel usage, control equipment; compliance status of sources. **SAROAD**: The following are common data reports: yearly data inventory by site, by pollutant, yearly or quarterly frequency distribution, composite listing; yearly report by quarters; air standards reports; parameter/sampling method/unit listing; raw data listing for 1 hour or 24 hours.	Services are available within EPA without restrictions, exchange agreements are available for other organizations with some restrictions on data available.
U.S. Environmental Protection Agency UNAMAP Users Network for Applied Modeling of Air Pollution	UNAMAP provides access to a network of air pollution models and associated meteorological and emissions data bases in order to determine effectiveness of controls and administer charges as required.	A variety of models pertaining to air pollution control will be made available to states, regions, and other qualified users.	A series of mathematical models for determining effects on air quality of various air pollution control actions.	Access available to regions, states, and other qualified users via a remote terminal network.	An inventory of models and capabilities will be made available so users can select appropriate models	Once on-line with the network, the user can select any model, data base, and test desired control strategies.	The system is available to EPA personnel and a variety of other eligible users.

Reproduced from
best available copy.

Table 14 (continued). FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - AIR

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
U.S. Environmental Protection Agency **AEROS** Aerometric and Emissions Reporting System	AEROS is comprised of input forms, procedures, programs, files, and reports established by the EPA to collect, maintain, and report information describing air quality and emissions sources. AEROS was formed by merging NEDS and SAROAD. NEDS and SAROAD forms provide the primary input to AEROS. AEROS now encompasses other information systems such as QAMIS, SOTDAT, HATREMS, SIPS, EDS, and RAPS as described below.	AEROS allows for: 1. Evaluation of state implementation plans 2. Evaluation of emissions and control equipment for developing new source performance standards 3. Support of enforcement of EPA regulations and inspection/monitoring 4. Determination of status and trends in air pollution for reports and progress evaluation 5. Studies of fuels, usage and availability 6. Research on monitoring of sources and ambient air for modeling	Punch cards and tape generated from NEDS and SAROAD forms. Forms are submitted to EPA by the states on a quarterly and semiannual basis	All AEROS reports can now be obtained directly from the National Air Data Branch. The objective is to provide full interactive and remote batch use of AEROS by all regional offices.	The AEROS manual	According to user requirements, various mathematical techniques can be used for data reduction and output of summaries, listings, raw data listings and published reports.	Similar to that described above
U.S. Environmental Protection Agency QAMIS - Quality of of Aerometric Data (see AEROS)	QAMIS is an interim system, for evaluating the quality control activities of groups who collect ambient air data, analyze the data, convert the data, and finally submit the data into SAROAD. There are no plans to update QAMIS as it will either be redesigned or superseded.	QAMIS consists of three record files: agency, laboratory, and site. In general, each file contains the results of general questionnaires solicited by EPA from representatives of each of the three quality control points for each monitoring system. There is the capability to "grade" the performance of agencies based on the data contained in QAMIS.	Questionnaires completed by agencies and laboratories responsible for acquiring data for input to SAROAD. The system analyzes quality control activities of these groups	N/A	N/A	The following information is available on a nationwide or state basis. 1. Site information 2. Site-pollutant information 3. Agency information	This system is used mainly by EPA personnel for the improvement of the SAROAD data base.

Table 14 (continued). FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - AIR

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
U.S. Environmental Protection Agency **SOTDAT** Source Test Data Storage	The system is designed to store and retrieve relevant technical data acquired during the performance of point source pollutant emission tests.	Data are included from source tests of stationary combustion facilities, chemical processes, mineral products industries, food and agriculture production, etc. Approximately 500 source tests were input to SOTDAT as of February, 1975. Annual increase is expected to be 300-500 source tests from EPA and other organizations.	Data is obtained from the EPA Emission Measurement Branch test reports, state and local air pollution control agencies, control equipment, manufacturers, consultants, and installations identified through information retrieved from the NEDS point source file.	System not yet operational	Source Test Data System (SOTDAT) National Air Data Branch - Monitoring and Data Analysis Division August, 1973 by J.H. Sutherland W.M. Vatavuk of E.J. Dale & J.B. Turner, System Sciences, Inc.	Data can be output according to specific pollutant; SCC codes; or by name and address of source.	Available on a time sharing basis to OAQPS and EPA personnel.
U.S. Environmental Protection Agency **HATREMS** **Hazardous and Trace Substance Inventory System**	The system is being designed to store operating parameters and annual emissions of sources of noncriteria pollutants. **HATREMS is included in the NEDS file. The HATREMS** source identification hierarchy is plant, point source, process, and pollutant.	HATREMS is comprised of two basic data files: point and area sources. A great deal of data included is derived from the NEDS file. The system is in the final stages of file maintenance and program design.	Emission factors from AP-42 and EPA 450/2-73-001, Emission Factors for Trace Substances, will be used to develop the initial data base.	System not yet operational	Currently under development	Similar to NEDS	When system is developed, access will be on a basis similar to NEDS.
U.S. Environmental Protection Agency **SIP** State Implementation **Plans**	The system stores the full text of all-state implementation plan regulations and subsequent revisions	The file contains 5000 state regulations, with expected addition of maximum of 200 pages of revised or new regulations per year.	The complete text of all State Implementation Plans for the purpose of air pollution abatement.	Access is available through NADB		Two outputs are available: 1. Full text retrieval of each regulation as it applies to one of approximately 160 identifying codes (e.g.) source surveillance record keeping or SO_x control regulations for stream electric power plants. 2. Total number of regulations that meet the retrieval specifications.	

Table 14 (continued). FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - AIR

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
U.S. Environmental Protection Agency EDS Energy Data System	EDS is currently under design and is intended to integrate all energy-related air quality data presently in EPA's data banks (see above).	EDS will contain fuel use summaries by geographical region and fuel consumption category; emissions and control equipment at large fuel burning sources; regulations applicable to fuel burning sources; compliance schedules; modeling results; and ambient air quality data in vicinity of large power plants.	All energy related data available in other EPA data banks.	System not yet operational		Output will be in a form similar to NEDS	
U.S. Environmental Protection Agency and Federal Power Commission Cumulative FPC-Form 67 Data System	The FPC collects data yearly from each power plant greater than 25 MW capacity and incorporates them into the Form 67 data system. Each boiler within each plant is assigned applicable NEDS plant and point identification codes and SCC codes. The FPC-67 system is completely compatible with NEDS and is accessible by a number of NEDS retrieval packages.	Information includes monthly and annual fuel use by boiler with associated sulfur and ash content; and detailed breakdowns of environmental control systems and costs. Form 67 includes 400 subject items and is completed by approximately 800 plants.	FPC form 67 questionnaire as completed by power plants of greater than 25 MW capacity. EPA receives coded data on magnetic tapes.	Access is available through NADB, which maintains a file of FPC-67 data on microfiche or on the original FPC questionnaires. A cross reference table between NEDS ID and FPC plant ID allows for use of NEDS retrieval codes.	The AEROS manual Volume III - Summary and Retrieval Manual Contract No. 68-02-1376 September, 1975	The complete FPC-67 information for all years for a given power plant can be retrieved. Selection can be made by geographic area, NEDS plant I.D., NEDS point I.D., SCC code, or fuel type.	Use restrictions are similar to NEDS
U.S. Environmental Protection Agency APTIC Air Pollution Technical Information Center	Collects and disseminates all domestic and foreign technical literature pertaining to air pollution. Services include: a. monthly abstracts b. literature searches c. response to inquiries concerning the dissemination of federally produced air pollution air pollution related documents. d. preparation of air pollution bibliographies.	Air pollution effects, atmospheric interactions, measurement, and control. 50,000 technical documents, hard copy and microfilm.	Domestic and foreig serials, patents, preprints, technical society papers, proceedings, and U.S. Government reports.	Accessible by telephone to the Air Pollution Technical Information Center, Research Triangle Park, North Carolina. 919-549-8411	Unknown	Technical documents in hard cover on microform Air Pollution Abstracts available monthly from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402	Free services primarily intended for EPA only; some services also free to qualified requesters.

Table 15. FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - WATER

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
U.S. Environmental Protection Agency **STORET** Storage and Retrieval of Water Quality Data	Storage and retrieval system for environmental data related to the discharge of pollutants to waterways. STORET provides information on water quality standards, waste discharges, abatement needs, construction costs, implementation schedules, and manpower needs. STORET is intended to aid in determining cause and effect relationships of water pollution.	Nationwide data base with data on 20,000 pollutant discharges and 20 million monitoring observations from over 150,000 locations. STORET monitors data on ambient conditions in the nations waterways.	Data gathered through permits issued for wastewater discharge, monitoring data collected by a variety of agencies at the federal, state, and local levels, stored as the result of various laboratory analyses of water samples.	Access by remote users via telephone terminals in 350 locations including 10 EPA regional offices and offices in 40 state capitals.	The STORET Handbook	Data base available as tape, punched cards, and computer printout.	Direct usage limited to primary pollution control authorities on the federal, state, and local levels.
U.S. Environmental Protection Agency **ENVIRON** Environmental Information Retrieval On-Line	EPA-wide, on-line, full text data storage and retrieval system utilizing the Computer Network (COMNET) in Washington D.C. The primary input in environmental literature and data received from various environmental monitoring and surveillance networks.	Data collection and literature searching in multiple fields of environmental concern.	Input from active and proposed R&D project descriptions, published literature, and various environmental quality surveillance networks.	EPA users by telephone throughout the U.S. The user needs keyboard terminals with EBCDIC correspondence or ASCII codes for on-line access to data.			Commercial access available on contract basis through Informatics, Inc., Rockville, Md.

Table 15 (continued). FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - WATER

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
U.S. Environmental Protection Agency GPSF General Point Source File	GPSF collects and analyzes data describing unique point sources of water pollution discharge, and institutes data quality control procedures.	Enables user to specify report information and format. User can select discharges according to discharge data conditions, select parameters for retrieval, retrieve various levels of the data, and design a specific output format.	Input data is derived from other computerized systems such as STORET after appropriate validation and editing.			User can design his own output format.	
U.S. Environmental Protection Agency NEI National Estuarine Inventory	NEI compiles information on the coastal zones of the U.S. to identify present and potential users, and the extent of pollution damage.	NEI serves as a repository for all estuarine data without regard for its individual characteristics, volumes, or special processing needs. Complete flexibility in data processing. The data base consists of 200 million items.	New information cataloged, validation criteria are determined for each data element, update characteristics are determined, and a standard print format is designed.			A standard print format is output. NEI is designed to have complete flexibility in data processing.	
U.S. Environmental Protection Agency Water Quality Standards	System provides EPA headquarters and regions the various individual state water quality standards on microfiche for analyses and reference.	Water quality standards including numerical and narrative criteria applied to specify stream use classifications; and an antidegradation statement.	Water quality standards are established by the states, and reviewed for approval by the EPA regional office. Upon acceptance, they are relayed to headquarters for formatting and microfiching.			One copy of final microfilm is sent to each EPA region.	

Table 15 (continued). FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - WATER

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
National Water Data System (NWDS) U.S. Geological Survey Water Resources Division	The NWDS was established to assess the quality of U.S. water resources. NWDS provides statistical data and summary reports to planners, developers, and managers. In the future, NWDS will identify and make available to all users all water data acquired in the U.S. by government and private interests.	Surface water stage and discharge; chemical quality parameters; radiochemistry; sediment; pesticide and certain biological concentrations in water, ground and surface water levels; geologic data on ground water; flood frequency and inundation mapping.	Measurements and observations collected by U.S. Geological Survey, states, counties, and local interest groups. 9,000 streamflow gauging stations 4,000 water quality measuring stations 30,000 groundwater observation wells Data back to 1890		Catalog of information on water data	Memorex 1600 computer output on microfilm system; publication data available on magnetic tape or cards; and 9-channel 500 BPI. tapes are available.	Services are available without restrictions; users are required to pay the computer costs involved in the selection and duplication of data.
Water Resources Scientific Information Center (WRSIC) Network U.S. Department of the Interior	Organized to disseminate information to the water resources community via state of the art reviews and computer-aided retrieval of pertinent literature. WRSIC consists of 3 information processing centers located at Univ. of Wisconsin, Cornell Univ., and North Carolina State Univ., which are linked to computer facilities at the Univ. of Oklahoma Research Institute and Oklahoma State Univ., which acts as coordination and evaluation of network activities. The 3 centers provide technical consultation, reference service, and library services to each of 3 multistate regions.	Water resources supply conservation, management, protection, law, engineering, planning, and pollution; an interdisciplinary coverage of the natural, physical, and social sciences related to water resources.	Literature, research in progress, patents, conference proceedings, final reports, and abstracting and indexing services. Primary input sources include WRSIC supported "centers of competence," the 51 water resources research institutes, and grantees and contractors of Office of Water Resources Research and other federal water agencies.			Computer literature searching available but no magnetic tapes are presently available.	Abstract journal, annual catalog, computer searches periodic bibliographies, and state of the art reviews available for purchase without restrictions.

Table 15 (continued). FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - WATER

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
U.S. NOAA (National Oceanic and Atmospheric Agency) Environmental Data Index (ENDEX)	The ultimate goal of the system is to maintain files of available marine environmental data for all United States coastal waters. The file descriptions give the types of records and data held by federal, state, and local government agencies, industry, and universities. The system is essentially a reference library of available information.	The files pertain to a wide variety of pollution-related coastal water characteristics. Information regarding when a particular program was started, what parameters are monitored, where analysis is performed, etc., is contained in the files.		By request, along with stipulation of type and range of information required.	Available on request from any EDS (see below) center or library.		No restrictions. Services provided on a reimbursable fee basis.
U.S. NOAA Environmental Data Service (EDS) National Oceanographic Data Center (NODC)	NODC acquires, processes, exchanges, stores, and retrieves globally oriented physical, chemical, and biological data related to oceanography. NODC provides data compilations along with evaluations of data accuracy. Services include: abstracting and indexing; data collection and analysis; literature searching; consulting; microreproduction; and research into ENDEX (see above).	Data from all oceans, seas and estuaries.	Data submitted by foreign and domestic corporations, national data centers, and the World Data Center system.		User's guide for NODC data processing systems.	Data tapes are available in various formats and combinations.	Requests should contain: 1. definition of required data 2. geographic area 3. other pertinent information Small amounts of data free of charge, otherwise cost estimates made and receipt of funds required.
Office of Water Data Coordination (OWDC) U.S. Geological Survey - Water Resources Division	The purpose of OWDC is to coordinate the acquisition of water data by federal agencies; design a national water data network; and establish a catalog of information on water data acquisition activities. (See NWOS below). Other services include preparation of indexes giving acquisition activities, responses to requests for information, and assistance to users in obtaining data on acquisition activities).	All water data acquisition activities, including data collection, processing, storage, retrieval, and dissemination; also included are the identification of standardized procedures for acquiring and handling water data and quality control techniques.	All input from federal and non-federal organizations acquiring and or using water data. covers: 24,000 surface water stage stations 18,000 water quality stations 29,000 ground water observation wells 1,800 aerial investigations		Catalog of information on water data 21 volumes corresponding to U.S. water resource regions		Services are available without restriction.

Table 15 (continued). FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - WATER

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
U.S. National Oceanic and Atmospheric Administration, National Ocean Survey, Lake Survey Center	Lake Survey Center studies the Great Lakes and their outflow rivers, Lake Champlain, New York State Barge Canal, and the Minnesota-Ontario Border Lakes. It compiles and publishes charts and related material, collects data related to the Great Lakes and issues these data in the form of summaries and technical reports.	Hydrographic surveys, charts and cartography, water levels, motion and river flow, water characteristics and hydrology, and limnologic systems.	Field observations, survey drawings, aerial photographs, notebooks, computations, soundings, published literature, data from vessels and field parties, paper and magnetic tape, punch cards and printouts.	The Center uses a Xerox Data Systems Sigma 3 Computer.	A list of technical publications and charts, and a guide to ordering publications are available through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. or from the Distribution Office in Detroit, Michigan.	Annual Data Summaries, Field Activities Reports, and Indexes of Area Coverage Surveys are issued. Microform copies of computer holdings are available. Data listings and bibliographies generated by literature searching are also available.	Services available to all without restrictions.
University of California, Water Resources Center	WRC serves State of California and the West by funding, coordinating and disseminating data concerning water resources. The Center makes referrals to other agencies and specialists in the water field. Two archives are maintained which are collections relating to all aspects of development and use of water in California and the West, and on water resources in general.	Engineering, economic, social and legal aspects of water; water as a natural resource and its use; irrigation and reclamation; flood control; municipal and industrial water uses and problems; water rights; water development projects; associated environmental problems and concerns.	Reports and information received from a variety of public and private sources.	Contact University of California, Water Resources Center, Davis, California 95616		The Center issues research reports, pamphlets, conference reports, and bibliographies. On-site use of literature collections are available.	Services available to all without restriction.
U.S. Environmental Protection Agency Region 5 - Chicago Power Plant Program Management Information System	System will maintain location and technical data on thermal pollution from power plants and the status of their permits. Monitoring process is designed to assist the enforcement procedure.	System will produce a sorted list of power plants along with identification of receiving waters, type, heat load, priority, dates of operation, and 7 year average flow.	Monitoring data from power plants located within Region 5.	Contact the Power Plant Program Management Information System, EPA Region 5, 230 South Dearborn, Chicago, Illinois 60604		User can ask the file for characteristics, give limits and extract data.	Services are provided primarily for EPA use.

Table 16. FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - SOLID WASTE

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
U.S. Environmental Protection Agency Office of Solid Wastes Management Programs Solid Wastes Information Retrieval System (SWIRS)	SWIRS maintains a file of abstracts of publications concerning solid waste management. SWIRS responds to technical inquiries, provides literature searches and compiles bibliographies on solid waste.	Solid waste management; water pollution; air pollution; urban, industrial and environmental health.	Books, patents, vendor's catalogs, and scientific periodicals.	Contact EPA, Office of Solid Wastes Management Programs, 1835 K. St., N.W., Washington, D.C. 20460	1. Information Retrieval Services of EPA's Office of Solid Waste Management Programs. 2. User's Guide to the Solid Waste Information Retrieval System Thesaurus. Both documents are available on request.	Solid waste publications, abstracts and bibliographies.	SWIRS is open to outside users provided requests are channeled.

Table 17. FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - NOISE

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
U.S. Environmental Protection Agency Office of Noise Abatement and Control Noise Information Retrieval System, NOISE	NOISE serves as an integrated, centralised information center that collects technical and nontechnical data on noise and noise sources. NOISE supplies copies of any information abstract to interested individuals. NOISE is a part of the ENVIRON system.	All aspects of environmental noise, including: aircraft, truck, train, bus, and automobile noise, ultra and infrasonic sounds, health and biological effects of noise, abatement and control of noise, measurement standards and methodology, and legal and enforcement experience. NOISE consists of ~15,000 articles, 1/5 of which have been computerized.	Journals, newspapers, professional and trade papers, government publications, EPA hearings, reports to Congress, and witness statements. Special efforts have been made to acquire data from Western Europe, Japan, and the USSR.	Part of the NOISE data base has been computerized and is accessible via a terminal linked to an IBM 360-65 computer system.	A thesaurus to be used with the NOISE data base can be provided upon request.	Output consists of either complete referencing to literature of interest or copies of publications.	Manual literature searching is available to all without charge.

Table 18. FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - TOXICOLOGICAL SUBSTANCES

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
Oak Ridge National Laboratory Environmental Information System Office - EISO, P.O. Box X, Oak Ridge, Tennessee 37830	EISO is composed of topical, mission oriented environmental information centers, various data base groups, scientific project teams, and a unit which provides response and referral services to the environmental research community. Component information centers include: the Toxicology Information Response Center (TIRC), Toxic Materials Information Center (TMIC), Environmental Mutagen Information Center (EMIC), Energy Information Center (EIC), Current Energy Research and Development, and Environmental Response and Referral Service (ERRS).	EISO provides abstracting and indexing input to all its information centers and data bases, consulting services in environmental, computer, and information system disciplines, and literature searches. The Office issues state-of-the-art reports on the topics of toxicology and pesticides. EISO provides coverage of environmental research including: ecological sciences, materials resources and recycling, environmental impact of electrical energy, and regional modeling.	EISO inputs a number of commercially available computer ized files including CA Condensates, BA-Previews, Bioresearch Index, Nuclear Science Abstracts, Chemical and Biological Sections of CA (CABS), and Government Research Announcements (GRA).	Contact ORNL, Environmental Information System Office P.O. Box X, Oak Ridge, Tennessee 37830 The Office uses IBM 360-75 and 360-91 computers.	The Environmental Directory, a computerized compilation of information centers, research projects and individual investigators.	EISO maintains a large number of data sets on magnetic tape and large data bases not formally established as information services are accessible through EISO. EISO has access to ORNL libraries, Information Division. Advisory and consulting services are also available.	Services are available to U.S. government agencies, their contractors, research and educational institutions, and industry.
Toxic Materials Information Center (TMIC), Environmental Information System Office, Oak Ridge National Laboratory	The objective of the system is to establish a data base on environmental levels of toxic materials. TMIC answers inquiries, provides R & D information, provides literature searching and abstracting and indexing services, distributes publications, makes referrals to other information sources.	Two classes of materials are included in data base: toxic metals and synthetic and natural organic compounds. Types of data are: materials balances in and around mining, smelting, and power facilities, natural and induced levels toxic and potentially toxic materials in various areas of the country, information on the levels of toxic substances in plants and animals inhabiting these areas.	Published literature, conference papers, and internally produced reports.	On site use of collection is permitted.		Publication abstracts and bibliographies, and data listings. Portions of data base can be made available externally on magnetic tape.	Services are available to those with a professional interest in the ecology and analysis of trace contaminants, both inside and outside ORNL.

Table 18 (continued). FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - TOXICOLOGICAL SUBSTANCES

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
Oak Ridge National Laboratory Environmental Mutagen Information Center, EMIC	EMIC was established to accumulate, store, and disseminate all information pertinent to chemical compounds in the environment which have been tested for mutagenicity. The Center works with two other information centers sponsored by ORNL, the TMIC and TIRC, in areas of mutual interest to provide comprehensive coverage to users of the other centers.	Chemical mutagenesis, including genetic effects of drugs, food additives, cosmetics, and industrial chemicals.	Journal articles, laboratory reports, symposium proceedings, abstracting publications, scientific newsletters and bulletins, and commercially available computerized data bases.	The EMIC uses an IBM 360 computer. Contact ORNL, Environmental Mutagen Information Center, P.O. Box Y, Bldg. 9224, Oak Ridge, Tennessee 37830	EMIC issues annual indexed bibliographies of the chemical mutagenesis literature.	Publication abstracts and bibliographies generated from computer literature searches. State-of-the-art reviews on currently important subjects are also available.	Services are available without restriction to the scientific community.
Oak Ridge National Laboratory Toxicology Information Response Center (TIRC)	TIRC was formed to serve as national and international center of toxicology information. One of TIRC's principal functions is to provide literature searches, answers to toxicological questions, production of annotated bibliographies, critical reviews, and state-of-the-art reports.	Toxicology, including: pharmacology, adverse effects, untoward reactions, drug interactions, side effects, biotransformation, pesticides, food additives, metal, chemicals, carcinogenicity, veterinary toxicology, industrial chemistry, and environmental pollutants.	Center utilizes various computerized services such as MEDLINE and TOXLINE.	The Center uses the Environmental Information System Office equipment consisting of IBM 360-75 and 360-91 computers.	TIRC publication list is available on request.	Bibliographies generated from literature searches and state-of-the-art reports.	Services are available without restrictions.
Oak Ridge National Laboratory Ecological Sciences Information Center, ESIC	ESIC provides information support to the Environmental Sciences Division of the Oak Ridge National Laboratory. Services include identification, collection, analysis, storage, and retrieval of data relevant to the radioecology interests of sponsors.	Radioecology including radionuclide cycling in various ecosystems, radiation effects on ecosystems or their components, basic ecology, and thermal effects and other aquatic impacts; special emphasis is given to the environmental aspects of plutonium and uranium.	Input data is selected from a complex of specialized libraries, current awareness services from automated sources (NSA, BA, CA, and GRA), and individual collections of material.	Computerized information files are available on-line through a working relationship with the Environmental Information System Office.		Publication abstracts and indexes, bibliographies compiled from literature searches, and data listings.	Services are available to all, with requests answered on the basis of availability of staff and resources.

Table 18 (continued). FEDERAL DATA RETRIEVAL AND INFORMATION SYSTEMS - TOXICOLOGICAL SUBSTANCES

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manual available	Form of data output	Use restrictions
U.S. Public Health Service **National Institute of Occupational Safety and Health NIOSH** **Technical Information Services Branch, TISB**	The TISB disseminates scientific and technical information on occupational safety and health. TISB answers questions concerning industrial health and maintains an information storage and retrieval system for literature covering occupational safety and health.	TISB includes information on all aspects of occupational health including industrial hygiene, medicine, toxicology, pathology, engineering, nursing, and chemistry. Approximately 20,000 documents are incorporated in the system.	Derived from current literature on occupational safety and health.	Contact NIOSH Division of Technical Services, Technical Information Services Branch, P.O. and Court House Building, Cincinnati, Ohio 45202	A list of publications is available from the Office of Technical Publications, NIOSH.	Computer literature searches, copies of solicited publications, etc.	Services are available to all, limited only by staff time and work load.
U.S. Public Health Service **National Institute of Environmental Health Sciences, NIEHS Information Services**	Information Services serves the information needs of the scientific staff and administrators of the NIEHS. The Institute maintains a library and provides bibliographic services through MEDLINE to outside requestors.	Mutagenesis; toxicology, pharmacology, teratology; veterinary science and technology, environmental pollutants, analytical methodology.	Derived from EPA publications, Edgewood Arsenal reports, NIOSH, and the EPA Pesticide Information Center.	NIEHS library and computer literature searching through MEDLINE.		The Institute maintains a library (4000 volumes and periodicals) and provides bibliographic services both manually and by outline terminal through MEDLINE.	Services intended for NIEHS personnel, others may use library during work hours.
CHEMLINE **Chemical Dictionary on-Line**	This system is sponsored by the Toxicology Information Program and the Chemical Abstracts Service.	Approximately 60,000 chemical substances identified by CAS Registry Numbers, molecular formulas, preferred chemical nomenclature, etc., can be searched online.					
U.S. National Library of Medicine **Toxicology Information Program, TIP** **TOXLINE**	TIP was established to provide the scientific community with a toxicology information service. TOXLINE is a nationwide, on-line literature retrieval service.	TOXLINE covers human and animal toxicity studies, effects of environmental chemicals and pollutants, adverse drug reactions, and analytical methodology. The data base includes approximately 325,000 references.	TIP obtains files from various private and government sources.	TOXLINE can be accessed by different types of terminal devices at many locations. Entry points to the computer are located throughout the U.S.		Whole text output of over 270,000 citations are available.	Services available to scientific community without restriction. Direct requests to Director, Toxicology Information Response Center, Oak Ridge National Laboratory, P.O. Box Y, Oak Ridge, Tennessee 37830.

Table 19. FEDERAL DATA RETRIEVAL SYSTEMS - TOTAL ENVIRONMENT

Name of system and contact	Brief description	Scope	Input data sources	Access to system	Users guide manuals available	Form of data output	Use restrictions
U.S. Environmental Protection Agency National Environmental Research Center (NERC) Information Center and Library	Information center and library of NERC is scientific and technical information focal point for the EPA. Computer literature searches of 33 data bases with citations to 97 million documents. Book catalog made available for participating EPA libraries	Air and water pollution (including standards and analysis), solid waste, noise, thermal pollution, radiation, pesticides, and related ecological and environmental topics. Major emphasis is on water quality, with such peripheral subjects as chemistry, engineering, biomedicine, and microbiology.	Input from U.S. National Technical Information Service, U.S. Government Printing Office, and states and universities. Periodicals, reports, proceedings, newspapers, and computerized data bases.	Data bases available through online or batch services at Univ. of Georgia, Lehigh Univ., Informatics, Inc.; Battelle Memorial Institute, Univ. of Cincinnati, and Ohio State Univ.	Contact NERC Information Center and Library, Cincinnati, Ohio 45268	Bibliographies, microreproduction of publications, full text copies, and library loan are available	Computer searches are available to EPA staff, consultants, and contractors; all other services are available to all participating libraries.
Ecology Forum, Inc. Environment Information Center EIC The Environmental Clearinghouse, Inc., Washington, D.C., is an affiliate and serves as its input agent for congressional and other government information.	EIC is a computer assisted central data bank which gathers, indexes, abstracts, analyzes, and disseminates information on environmental matters. EIC monitors, abstracts, and cross-references information in some 500 scientific publications. Ecology Forum, a nonprofit organization, attempts to fill information and communications gaps, to facilitate access to environmental data and to increase the speed with which new information can be assimilated.	Environmental issues, including air, noise, land pollution; wildlife; geophysical change, energy, recreation, transportation; population control, and ecological imbalance.	Materials from primary and secondary source journals, research reports, conference proceedings, government and private documents, films, books, and legislation.	Information available to subscribers in a biweekly publication or through computer searches and bibliography assemblies requested by mail or telephone order.		Abstracted items are available in microfiche or hard copy form on a single item or subscription basis.	Services are available to all; retrieval services are for personal reference purposes only.

Table 19 (continued). FEDERAL DATA RETRIEVAL SYSTEMS - TOTAL ENVIRONMENT

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manuals available	Form of data output	Use restrictions
Pollution Abstracts, Inc. Pollution Abstracts	This periodical service indexes and abstracts journals on environmental pollution. It performs literature searches for outside users on a contract basis and provides a document retrieval service for subscribers to its journals.	This service covers 30,000 citations in all major areas of pollution. Pollution Abstracts subscribes to 750 periodicals.	Domestic and foreign journals, technical reports, books, symposia, and government documents.	Subscription to Pollution Abstracts Pollution Abstracts, Inc. P.O. Box 2369 La Jolla, California 92037	N/A	Bi-monthly periodical	Services and publications are available to subscribers only; manual literature services are offered on a contract basis.
Battelle Memorial Institute-Columbus Laboratories Energy Information Center (EIC) 505 King Avenue Columbus, Ohio 43201 (614) 299-3151 x3711	The EIC was established as part of the Battelle Energy Program to provide energy information and data to users inside and outside Battelle who are involved in energy related research. The EIC is intended to be the nations major source of evaluation energy information and data.	Present coverage includes coal, oil, natural gas; nuclear, geothermal, solar, tidal, wind, and hydro sources of energy. All aspects of energy systems are covered from resource extraction to final consumption.	Input is derived from 120 journals, technical reports, and other appropriate reference materials.	User needs an appropriate remote terminal and communication link.		Results of computer literature searching, and data listings	Services are available to all with interest in the nations energy problems.
U.S. Environmental Protection Agency Environmental Impact Statement System	System will assist in monitoring environmental impact statements through the review process and by generating reports for publishing in Federal Register.	The system will identify impact statements which have been commented upon, statements under current review and number of statements per region, in order to monitor processing of statements.	Office of Federal Activities prepares input from Environmental Impact Statement logs which are received weekly from all EPA regions.			Four reports produced: 1. Bi-weekly register 2. Monthly frequency report 3. Quarterly statement 4. Listing of total file off-line.	

Table 19 (continued). FEDERAL DATA RETRIEVAL SYSTEMS - TOTAL ENVIRONMENT

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manuals available	Form of data output	Use restrictions
U.S. Environmental Protection Agency Program Review and Evaluation System (PRES)	PRES compiles in one location specific information on all monitoring oriented programs operated throughout EPA. Central file used as starting point for all agency technical personnel to identify where and who is performing specific monitoring operations.	PRES will identify the following information for a particular monitoring program: 1. Who is performing the work 2. Where work being done 3. Major results	File includes all fiscal year 1973 accomplishment plans for all monitoring operations performed at the National Environmental Research Centers by the EPA regions.				Use is intended primarily for EPA personnel.
Battelle Memorial Institute Environmental Information Analysis Center (EIAC)	Objective of the center is to provide a basis for information collected and used in support of various environmental research programs. The primary emphasis is devoted to environmental and health protection associated with nuclear facilities and activities. The center answers inquiries, provides consulting, reference, literature searching, abstracting and indexing services, provides R&D information, lends materials, permits onsite use of collection.	Powerplant siting; nuclear [illegible]; thermal effluent effects; water quality management; radionuclide cycling in the environment; system ecology, solid waste management; environmental monitoring and analysis, combustion research; environmental impact assessments; environmental aspects of urban regional planning; mathematical modeling of ecosystems; environmental information management.	Not a computerized service. Holdings include periodicals, technical papers, research and development reports, and other similar data.	Documents are manually accessible by an inverted coordinate index searchable by author, organization and key words.		Data are available on microfiche or hard copy, primarily in the form of abstracts.	Services are provided on a contract basis. Qualified users include government and industry.

Table 19 (continued). FEDERAL DATA RETRIEVAL SYSTEMS - TOTAL ENVIRONMENT

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manuals available	Form of data output	Use restrictions
The Center for Short-Lived Phenomena, Cambridge, Massachusetts United Nations Environment Program	The center has developed a major data base on existing, long-term pollution monitoring programs in 78 countries. It contains information on the purpose of each program, how the programs are administered and the pollutants monitored. Information is given on the physical medium monitored, geographical area covered, number of sites, sampling frequency, methods of sampling and data acquisition, measurement techniques, methods of sample analysis, precision of analysis, mode of data storage, and the date the program began.	The data base includes information on 1-1 monitoring programs in the United States. The data base includes administrative, operational, and technical data on each program. Programs covered include those monitoring SO_2, sulphates, POM, CO, CO_2, NO_x, oxidants, radioactive HC's, Hg, Pb, Cd, DDT, PCB's, asbestos, HC's, toxins of biological origin, nitrates, nitrites, ammonia, BOD, DO, pH, coliform bacteria, radionuclides, soluble salts of alkali metals and alkaline earth metals.	Information received from worldwide environmental monitoring programs.	Contact the Center for Short-Lived Phenomena 185 Alewife Brook Parkway Cambridge Ma. 02138 phone (617) 868-4793		A variety of outputs are available depending upon the specificity and detail required. For example, one can obtain a list of programs monitoring a specific pollutant in a given medium in a specific ocean area.	Fee charged for services, but available to all

Table 19 (continued). FEDERAL DATA RETRIEVAL SYSTEMS - TOTAL ENVIRONMENT

Name of system and sponsor	Brief description	Scope	Input data sources	Access to system	Users guide manuals available	Form of data output	Use restrictions
MERES **Matrix** of Environmental **Residuals for Energy Systems.** Sponsored by the Council of Environmental Quality CEQ	MERES is a computerized data base specifying the water pollution, air pollution, solid waste, land use, and occupational health effects of present and future energy systems. MERES also includes data on energy efficiencies and costs. A major reason for the development of MERES is to provide simplification of preparation and review of environmental impact statements, concerning energy related projects. The complete system including the MERES data base, computer software, and computational models is termed the Energy Model Data Base (EMDB).	Data is included relating to the entire spectrum of energy supply systems and environmental impact. The following activities are considered: resource, extraction, transportation, processing distribution, storage, conversion, electric generators, and end uses. For each activity, MERES contains coefficients estimating environmental impact, efficiency, and capital and operating costs. Energy sources covered include those derived from coal, oil, natural gas, nuclear fission, and new technologies such as coal gasification and liquefaction, oil shale, solvent refined coal, and fluidized bed coal combustion. Residuals specified in MERES include air, water, and solid wastes. Air pollutants covered are NO_x, SO_x, HC's, CO, and aldehydes. Water pollutants covered include acids, bases, dissolved solids, BOD, COD, and heat. Land impacts such as area required, are also considered.	Most of original data contained in MERES came from "Environmental Impacts, Efficiency, and Cost of Energy Supply and End Use" prepared by Hittman Associates, Inc. Updating and refinement of the data is a continuous process carried out at Brookhaven.	MERES data are stored in a computer at the Brookhaven National Laboratory, Long Island, N.Y. The data and programs for performing computations are available from the Brookhaven computer via remote terminal or on the users own computer system.	Energy Model Data Base. Users Manual. Brookhaven will provide copies of programs and data. Additional information concerning MERES and EMDB is available from the Energy/Environmental Data Group, Brookhaven National Laboratory, Upton, N.Y. 11973.	Data is available on magnetic tape and in the 2 printed volumes. Environmental Impacts, Efficiency, and Cost of Energy Supply and End Use. Information is presented in a matrix format. Columns are environmental residuals, energy requirements, and costs; and the rows are activities and processes involved in a particular energy resource.	The system is available to all on a cost basis.

APPENDIX D

POLLUTION LEGISLATION AND FUTURE PERSPECTIVES

INTRODUCTION

One important function of an environmental assessment is to assure compliance with federal, regional, state and local pollution and resource use statutes. Most pertinent federal regulations fall under the enforcement of the U.S. Environmental Protection Agency (EPA) but other agencies, such as the U.S. Public Health Service (PHS) and the U.S. Food and Drug Administration (FDA), set standards for release of various substances. A clear discussion of the EPA statutory authority is presented in a recent EPA publication.[1]

Although EPA has national authority for maintaining and improving the environment, a significant portion of the enforcement and setting of standards is carried out by state and regional agencies. For example, The Clean Air Act of 1970 called for EPA to set national ambient air quality standards for six pollutants: SO_x, particulate matter, CO, hydrocarbons, photochemical oxidants, and NO_x. The EPA has set standards for these substances which are to apply to the entire country. States, however, have the responsibility to draw up implementation plans to meet these criteria. These state (and in some cases regional and local) regulations often take the form of emission restrictions on individual facilities. Space does not permit a discussion or compilation of the various state regulations here, but these specific restrictions must be of prime concern to any energy system developer.

Preceding page blank

On another level, EPA directly regulates the emissions of certain species from several classes of stationary sources. These New Source Performance Standards (NSPS), where applicable to energy systems, will be indicated in the following sections.

Similar considerations pertain to water pollution. The Federal Water Pollution Control Act (FWPCA) as amended by Congress in 1972 sets as a goal the elimination of the discharge of all pollutants into navigable waters by 1985. An interim goal is that the level of water quality necessary for the protection of fish, shellfish, and wildlife shall be reached by July 1, 1983. To meet these goals, industrial dischargers must employ the best practiceable control technology by July 1, 1977, and use the best available technology by July 1, 1983. Again, states are required to develop implementation plans including effluent limits to meet federal strictures.

Table 20 summarizes the significant statutory authority of the EPA in the areas of air, water, solid waste, and noise pollution, and contains brief summaries of state responsibilities under these acts. The next section presents current federal standards developed by the EPA. The following section notes standards under consideration, and the final section discusses the sorts of regulations which can be expected in the future.

It must be emphasized that these federal, as well as state and local, standards are continually reviewed and updated. As a consequence, energy system developers must keep abreast of the Federal Register and local governmental publications. A convenient way of accomplishing this is to consult the Federal Regulations section of the Environment Reporter.[2] This document provides a continuous updating of all amendments and revisions to pollution regulations.

Table 20. FEDERAL LEGISLATION CONCERNING ENVIRONMENTAL ASSESSMENT ACTIVITIES

Area of legislation	Name of standard or proposal	Description	Scope	In relation to state role	Reference
Air	**National primary and secondary ambient air quality standards**	For 1. Sulfur dioxide 2. Particulate matter 3. Carbon monoxide 4. Photochemical oxidants 5. Hydrocarbons 6. Nitrogen dioxide	Under Section 109 of Clean Air Act — Primary: quality which EPA judges necessary to protect public health. Secondary: level of quality which EPA judges necessary to protect public welfare from known or anticipated adverse effects of pollutants.	The state may establish standards which are more stringent than the national standards.	40 CFR 50;[a] 36 FR 22384[b]
	Standards of performance for new stationary sources (proposed and promulgated) which may contribute significantly to air pollution which causes or contributes to the endangerment of public health or welfare	Standards should reflect "...the degree of emission limitation achievable through the application of the best system of emission reduction as determined.." by EPA.	Under Section III of Clean Air Act for categories of pollution sources such as coal burning plants, refineries and incinerators (stationary fossil fuel generating plants).	The state may establish any standards to the facility provided they are not less stringent than the federal standard. It also may require the owner of the facility to obtain any permits, licenses or approvals prior to construction or operation of the facility.	40 CFR 60; 36 FR 24876
	National emission standards for hazardous air pollutants (NESHAP)	(Section 111 of Clean Air Act) For 1. Asbestos - no visible emissions to outside air 2. Mercury - 24-hour standard - require stack sampling 3. Beryllium - 24-hour standard - require ambient and stack sampling		The state may establish any standards to the facility provided they are not less stringent than the federal standard. It also may require the owner of the facility to obtain any permits, licenses or approvals prior to construction or operation of the facility.	40 CFR 61; 38 FR 8820
	EPA regulations on energy related authority (Section 119 of Clean Air Act contained in the Energy Supply and Environmental Coordination Act of 1974)	Gives EPA authority to suspend orders converting steam electric power plants from oil or gas to coal if the use of coal results in an increase in emissions of any air pollutant for which national ambient standards have not been promulgated.	This is a potential requirement on coal related developments to identify all airborne emissions due to the possibility of EPA imposing emission standards.		40 CFR 55; 40 FR 18438, April 28, 1975

Table 20 (continued). FEDERAL LEGISLATION CONCERNING ENVIRONMENTAL ASSESSMENT ACTIVITIES

Area of legislation	Name of standard or proposal	Description	Scope	In relation to state role	Reference
Water	Water quality standards (effective 1983)	Define all planned uses of intra- and interstate and coastal waters intended to limit the amount and distribution of pollutants permitted in these waters. Four major components: 1. Stream use classification – four categories expressed in terms of recreational uses; 2. Criteria – specific amount and quality of each pollutant tolerable in designated waters; 3. Anti-degradation statement – certifying that degradation of water quality is prohibited except for necessary economic development; 4. Implementation and enforcement plan.	All surface waters (except those specifically approved by EPA for less stringent classifications)	Implementation of water quality standards will be through: 1. State continuing planning process 2. Permit program a. SCPP: states retain role for setting and enforcing water quality standards. In addition, they have the added duty of making certain that no effluent limitation written into a permit is inadequate to protect the water quality standard. The relationship between effluent discharges and water quality must be coordinated into a study and planning program subject to federal approval. b. Permit program: applies to both water quality standards and all effluent limitations.	40 CFR 120; 36 FR 22489, November 25, 1971
	Effluent limitations - Best practical technology - Best available technology	Maximum allowable rate of discharge, concentration or amount of a pollutant which may be released from a point source into any body of water. By July 1977, all plants must achieve the average of the best existing performance by well operated plants within each industrial category. By July 1983, all industries must conform to the very best control and treatment measures that have been or are capable of being economically achieved.	Set in two steps by EPA: 1. Best practical technology by 1977; 2. Best available technology by 1983. Add on treatment technology – includes process changes Add on treatment technology – greater emphasis on production changes	Permit program under the National Pollutant Discharge Elimination System (NPDES).	Section 301 of the FWPCA[c]

Table 20 (continued). FEDERAL LEGISLATION CONCERNING ENVIRONMENTAL ASSESSMENT ACTIVITIES

Area of legislation	Name of standard or proposal	Description	Scope	In relation to state role	Reference
Water	New source standards (promulgated) (National standards of performance for new sources) Effective 1974	Similar to the 1983 effluent limitations with added emphasis on further gains in effluent reduction through changes in the production process. Applicable where standards interfere with water quality goals in specific portions of navigable waters. New sources will not be subject to more stringent standards for either 10 years or period of depreciation – whichever is first.	Add on in-plant design, process controls, raw materials – all aspects	Permit program under NPDES	Section 306 of the FWPCA
	Pretreatment effluent standard (Effective July 1976 for existing plants and May 1974 for new plants)	Requiring any industry discharging into a municipal sewage treatment plant to pretreat its effluent so that it does not interfere with the operation of the plant or pass through the plant untreated or without adequate treatment. Effective July 1976 for existing plant and May 1974 for new plants.	Unlimited – any unit process controls needed to prevent excess pollutants into treatment plant. Enforced by EPA and municipalities in general.	The state in particular cases may impose pretreatment requirements stricter than those of EPA in order to meet effluent limitations in a NPDES permit for a publicly owned treatment works.	40 CFR 128, 38 FR 30982 Section 307 of the FWPCA
	Toxic Effluent Standards (Effective January 1975)	EPA must prepare a list of pollutants for which it will establish toxic standards. The standard may prohibit or limit discharge of the substance but must provide an "ample margin of safety."	Unlimited – any changes needed to prohibit or limit toxics – effective January 1975. EPA is to publish a list of pollutants[d] and effluent limitations for these pollutants.	Permit program under NPDES	Section 307 of the FWPCA

Tabel 20 (continued). FEDERAL LEGISLATION CONCERNING ENVIRONMENTAL ASSESSMENT ACTIVITIES

Area of Legislation	Name of standard or proposal	Description	Scope	In relation to state role	Reference
Water	Thermal discharges	EPA must establish federal limitations on thermal pollution. This is applicable to a point source and requires that the location, design, construction and capacity of cooling water structures reflect the best technology available for minimizing adverse environmental impact.	Discharges into water from all point sources.	While law requires EPA to establish federal limitations on thermal pollution, these may be waived by the state permit agency if the discharger shows that the standard is more stringent than necessary to protect important species of fish and shellfish. Once a thermal discharge limit is written into the permit, the discharger will not be subject to any more stringent standard for a 10 year period or the period of depreciation, whichever comes first.	Section 316 of the FWPCA 40 CFR 122, 39 FR 36176
Solid Waste	Solid Waste Disposal Act (1965) as amended by the Resource Recovery Act (1970)	1. construction, demonstration, and application of waste management and resource recovery systems for the preservation of air, water, and land resources, 2. technical and financial assistance to agencies in planning and developing resource recovery and waste disposal programs; 3. national research and development programs to develop and test methods of dealing with collection, separation, recovery, recycling, and safe disposal of nonrecoverable waste, 4. guidelines for the collection, transportation, separation, and recovery and disposal of solid waste; 5. training grants in occupations involving design, operation, and maintenance of solid waste disposal systems.	All solid wastes	Federal law encourages cooperation between States and localities. EPA makes grants to eligible States, municipal, interstate and intermunicipal agencies to survey solid waste disposal practices, to develop disposal plans, to demonstrate resource recovery systems, and to construct test facilities. Money is also provided for personnel training, involving management supervision, design, operation, and maintenance of pilot projects.	PL 89-272 (1965), PL 91-512 (1970), PL 93-14 (1973), PL 93-611 (1975)

Table 20 (continued). FEDERAL LEGISLATION CONCERNING ENVIRONMENTAL ASSESSMENT ACTIVITIES

Area of legislation	Name of standard or proposal	Description	Scope	In relation to state role	Reference
Noise	Noise Pollution Control Act of 1972				
	Sec. 5 - Identification of major noise sources; noise criteria and control technology	EPA must develop and publish criteria with respect to noise. This knowledge must useful in indicating the kind and extent of effects on public health which can be expected from differing qualities and quantities of noise. Publish information on the levels of noise under various conditions which are needed to protect public health within a margin of safety - Publish a report(s) which identify products which are major sources of noise and provide information for the control of noise.	Any major noise source as defined by EPA EPA has published "public" health and welfare noise criteria - July 27, 1973, EPA-550/9-73-002 EPA may review and revise any criteria or reports under this section	None	Sec. 5 - Noise Control Act
	Sec. 6 - Noise Emission Standards for Products Distributed in Commerce	EPA must publish proposed regulations for each product Which is identified as a major source of noise Noise emission standards are feasible Falls into the category of - Equipment for construction - Transportation equipment - Any motor or engine - Electrical or electronic equipment	EPA may prescribe regulations for any of the named categories and set noise emissions on these products based on criteria (under Sec. 5 (above))	With respect to any new product, the state cannot set any limit on noise emission which is not identical to regulations of EPA This does not deny the state (or local officials) to enforce controls on environmental noise of any product	(For products with regulations prescribed by EPA) Sec. 6 - Noise Control Act

[a] CFR - Code of Federal Regulations.

[b] FR - Federal Register.

[c] FWPCA - Federal Water Pollution Control Act.

[d] Those pollutants which, after discharge and upon contact with any organism, either directly from the environment or indirectly by ingestion through food chains, will cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions or physical deformities in such organisms or their offspring.

[e] PL - Public Law.

EXISTING STANDARDS

Air

Federal air pollution authority falls into three categories: ambient air quality (AAQ) standards which are to be achieved through State implementation plans; national emission standards for hazardous pollutants; and new stationary source performance standards. The AAQ levels, listed in Table 21, are divided into primary and secondary standards. Primary standards are those which if exceeded are judged to be detrimental to human health. These ambient levels are to be reached by 1975. Secondary standards, which are meant to protect animals, plants and property, have no set date for achievement.

To date, three species — mercury, beryllium, and asbestos — have been classified as hazardous air pollutants. Emission standards for these species from certain sources have been set and are shown in Table 22.

Standards for 17 types of new or substantially modified stationary sources have been established by the EPA.[3] Two of those source types are relevant to energy systems: steam electric generators having greater than 250 x 10^6 Btu/hour heat input, and storage vessels for petroleum liquids. The standards for these sources are shown in Table 23.

Water

Water pollution standards include water quality standards to be established by the states, effluent standards identifying the best practicable control technology available for existing and new industrial point sources, and effluent limitations for toxic pollutants.

Table 21. AMBIENT AIR STANDARDS[a]

Species	Averaging period[c]	Air quality standards[b]	
		Primary[a]	Secondary[a]
SO_x (as SO_2)	AAM	80(0.03)	60(0.02)
	24	365(0.14),1x	260(0.09),1x
	8	-	-
	3	-	1,300(0.49),1x
Particulate	AGM	75	60
	24	260,1x	150,1x
	8	-	-
Carbon monoxide	8	10,000(9),1x	10,000(9),1x
	1	40,000(35),1x	40,000(35),1x
Oxidant (as O_3)	8	-	-
	1	160(0.08),1x	160(0.08),1x
NO_x (as NO_2)	AAM	100(0.05)	100(0.05)
	24	-	-
	8	-	-
	1	-	-
Nonmethane (HC)	8	-	-
Hydrocarbons(HC) (as CH_4)	3	160(0.24),1x	160(0.24),1x

[a] Format for each entry is as follows: STANDARD $\mu g/m^3$ @ 760 mmHg & 20°C (Equivalent Value, ppm). The maximum allowable exceedance rate, if any, follows. This refers to the maximum number of times per year that the standard may be exceeded. For example, 1x means the standard may be exceeded only once per year.

[b] "National Primary and Secondary Ambient Air Quality Standards," Federal Register 36, #84, pp. 8186-8201.

[c] The averaging period is given in hours unless otherwise specified. AAM means Annual Arithmetic Mean Value and AGM means Annual Geometric Mean Value.

Table 22. SUMMARY OF HAZARDOUS AIR POLLUTANT STANDARDS

Pollutant	Affected facility	Limitation
Mercury	Mercury ore processing facilities, Mercury cell chlor-alkali plants	Not more than 2300 gm/day for the entire facility.
Beryllium	Extraction plants, foundries, ceramic manufacturing plants, beryllium waste disposal incinerators, propellant plants, machine shops processing alloys with > 5 percent Be.	Not more than 10 gm/day (Option of meeting ambient level of 0.01 $\mu g/m^3$ if 3 years of ambient data available).
	Rocket testing facilities	Limited to 75 $\mu gm\text{-}min/m^3$
Asbestos	Asbestos mills, manufacturing operations	No visible emissions or use control equipment meeting specific performance characteristics
	Spraying of asbestos fireproofing and insulation that contains more than 1 percent asbestos on buildings, structures, pipes and conduits.	Banned
	Spraying of asbestos fireproofing and insulation that contains more than 1 percent asbestos on equipment and machinery.	No visible emissions
	Use of asbestos mill tailings on roadways	Banned except on asbestos ore deposits
	Demolition operations	Good control practices are required

Table 23. SUMMARY OF AIR EMISSION STANDARDS FOR NEW OR SUBSTANTIALLY MODIFIED SOURCES[3]

---

1. Steam Generators (> 250 million Btu/hour heat input)
   - (a) Particulate Matter:
     - (1) 0.1 lb per million Btu heat input (0.18 grams per million calorie)
     - (2) No more than 20 percent opacity visible emissions, except for 2 minutes in any hour visible emissions may be as great as 40 percent opacity.
   - (b) Sulfur Dioxide:
     - (1) 0.8 lb per million Btu heat input (1.4 grams per million calorie) when oil is fired.
     - (2) 1.2 lb per million Btu heat input (2.2 grams per million calorie) when coal is fired.
   - (c) Nitrogen Oxides (as NO_2):
     - (1) 0.20 lb per million Btu heat input (0.36 grams per million calorie) when gas is fired.
     - (2) 0.30 lb per million Btu heat input (0.54 grams per million calorie) when oil is fired.
     - (3) 0.70 lb per million Btu heat input (1.26 grams per million calorie) when coal is fired.
2. Storage Vessels for Petroleum Liquids
   - (a) Hydrocarbons:
     - (1) If the true vapor pressure of the petroleum liquid, as stored, is equal to or greater than 78 mm Hg (1.5 psia) but not greater than 570 mm Hg (11.1 psia), the storage vessel shall be equipped with a floating roof, a vapor recovery system, or their equivalents.
     - (2) If the true vapor pressure of the petroleum liquid, as stored, is greater than 570 mm Hg (11.1 psia), the storage vessel shall be equipped with a vapor recovery system or its equivalent.

As in the area of air pollution, source performance standards have been issued for steam electric generating plants. These guidelines, which are applicable to existing as well as new sources of all sizes, are summarized in Table 24.

Solid Waste

There are no federal emission or effluent standards per se for solid waste disposal. Rather, a series of guidelines and recommended procedures have been developed which are applicable to federal installations. Under the Resource Recovery Act, states have the primary responsibility for the management of solid waste material. Table 25 highlights and compares federal and state guidelines.

PENDING STANDARDS

Air

Emission standards for 14 stationary sources presently under review by EPA have been published in the Federal Register. Reference 3 contains a discussion of the procedures and legal requirements involved in the establishment of new source performance standards. Five of these sources are related to energy systems and are listed along with affected facilities and controlled pollutants in Table 26.

Water

Interim primary standards for drinking water soon to be promulgated in the Federal Register have recently been issued by EPA.[4] Pending review and public comment, these standards which are to be enforced by the states are to become effective in June 1977. These interim standards are listed in Table 27.

Table 24. WASTEWATER EFFLUENT GUIDELINES AND STANDARDS - STEAM ELECTRIC GENERATING POINT SOURCE CATEGORY[a]

Prominent Waste Stream Affected	Concentration All values in mg/l	
	Effluent Characteristics	BPT,[b] BAT,[c] and NS[d]
Feedwater treatment	pH PCB's	6-9 0

	Effluent Characteristics	Maximum daily discharge			Average Daily Discharge for 30 Consecutive Days		
		BPT	BAT	New Source	BPT	BAT	New Source
Equipment cleaning blowdown	TSS	100	100	100	30	30	30
	Oil and Grease	20	20	20	15	15	15
	Copper	1	1	1	1	1	1
	Iron	1	1	1	1	1	1

		BPT		BAT		New source						
		Low Volume and Ash Transport		Low Volume and Fly Ash Sluicing		Bottom Ash Transport		Low Volume		Bottom Ash Transport		Fly Ash Transport
	Effluent Characteristics	Maximum Daily	Average Daily for 30 days	Maximum Daily	Average Daily for 30 Days	Maximum Daily	Average Daily for 30 Days	Maximum Daily	Average Daily for 30 Days	Maximum Daily	Average Daily for 30 days	
Fuel Handling Ash Handling	TSS	100	30	100	30	8	2.4	100	30	5	1.5	0
	Oil and Grease	20	15	20	15	1.6	1.2	20	15	1	0.75	0

	Effluent Characteristics	Maximum Concentration			Average Concentration			Maximum Daily Discharge			Average Daily Discharge for 30 Consecutive Days		
		BPT	BAT	NS	BPT	BAT	NS	BPT	BAT	NS	BPT	BAT	NS
Cooling	Free Available Cl	0.5	0.5	0.5	0.2	0.2	0.2			No detectable amount			No detectable amount
	Zn							-	1.0		-	1.0	
	Cr							-	0.2		-	0.2	
	P							-	5.0		-	5.0	

[a] Steam Electric Power Generating Point Source Category - Effluent Guidelines and Standards. Federal Register, Vol. 39, No. 196. October 8, 1974.

[b] Best practicable control technology currently available.

[c] Best available control technology economically achievable.

[d] New source.

Reproduced from best available copy.

Table 25. SUMMARY OF FEDERAL GUIDELINES AND STATE REGULATIONS FOR SOLID WASTE DISPOSAL PRACTICES

Federal guidelines	State regulations
Site selection:	
Consistent with local environmental standards and land-use plan	Site should be 100 to 300 feet from nearest surface water and 1000 feet from nearest potable water.
Design plans should include:	
Site hydrogeology evaluated for protection of groundwater resources	Generally 3 to 5 feet separation between high groundwater table and departed solid waste.
Characteristics of site soil should be evaluated	Soil case samples should be taken and analyzed
Consideration of environmental factors, climatological, and socioeconomic factors	Similar to federal
Determination of types and quantity of waste to be disposed	Quarterly reports may be required
Initial and final topographies of area at 5 foot intervals	Similar to federal
Surveys of the land use and zoning within 1/4 mile of site	Similar to federal
Location of all utilities within 500 feet	Similar to federal
A narrative description with drawings describing development and operation procedures	Similar to federal
Ultimate use of land disposal site	Generally the owner must maintain the site for 1 year after its final use
Proposed location of observation wells for testing	Underground water samples may be required for checking of leachates
Provision for surface water runoff	Surface should be properly graded with a slope between 1 and 15 percent
Proposed control of leachate generation	If leachate could be a problem, treatment is required
Site should meet air quality standards; e.g., fugitive dust	Similar to federal
Decomposition gases should be controlled	Similar to federal

Table 25 (continued). SUMMARY OF FEDERAL GUIDELINES AND STATE REGULATIONS FOR SOLID WASTE DISPOSAL PRACTICES

Federal guidelines	State regulations
Vectors should be controlled	Fencing required
The aesthetics of the area shall be maintained	Seeding of area
Operating practices:	
Daily cover should be applied at least 6 inches	Similar to federal
Intermediate cover when area will not be used for an extended period of time (1 week to 1 year) at least 1 foot	Similar to federal
Final cover should be at least 2 feet	Similar to federal

Table 26. SOURCES FOR WHICH STANDARDS HAVE BEEN PROPOSED AND REVIEW INITIATED[3]

Source	Facility	Pollutant
Coal cleaning plants	Air tables, thermal dryers	Particulates
Lignite-fired steam generators	Boiler	Nitrogen oxides
Sulfur recovery plants in petroleum refineries	Sulfur recovery plant	Total reduced sulfur and sulfur dioxide
By-product coke ovens-charging operation	Truck, railcar, barge and ship unloading and loading operations, and conveyors, cleaners and dryers	Particulates
Crushed stone plants	Crushers, screens, conveyor transfer points, surge and storage bins, and drilling operations	Particulates

Table 27. NATIONAL INTERIM PRIMARY DRINKING WATER STANDARDS

A. Maximum Contaminant Levels for Inorganic Chemicals

Contaminant	Level (mg/ℓ)
Arsenic	0.05
Barium	1
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate	10
Selenium	0.01
Silver	0.05

Fluorides

When the annual average of the maximum daily air temperatures for the location in which the community water system is situated is the following, the corresponding concentration of fluoride shall not be exceeded:

Temperature (in degrees F)	(in degrees C)	Level (mg/ℓ)
53.7 and below	12.0 and below	2.4
53.8 - 58.3	12.1 - 14.6	2.2
58.4 - 63.8	14.7 - 17.6	2.0
63.9 - 70.6	17.7 - 21.4	1.8
70.7 - 79.2	21.5 - 26.2	1.6
79.3 - 90.5	26.3 - 32.5	1.4

B. Maximum Contaminant Levels for Organic Pesticides

Chlorinated Hydrocarbons	Level (mg/ℓ)
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
Chlorophenoxys	
2,4-D	0.1
2,4,5-TP Silvex	0.01

THE FUTURE

Air

General expectations include timetables for compliance with AAQ standards and identification of additional hazardous air pollutants. Specifically, at least 18 additional sources are currently being surveyed for establishment of emission standards. Included in this category are particulate and hydrocarbon emissions from coke ovens[3] and sulfur and hydrocarbon emissions from coal gasification plants.[5]

Water

Future water effluent guidelines will evolve toward the goal of zero discharge by 1985 as spelled out in the Federal Water Pollution Control Act.

REFERENCES

1. The Challenge of the Environment: A Primer on EPA's Statutory Authority. December 1972. (Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)

2. Environment Reporter. The Bureau of National Affairs, Inc., Washington, D.C. 20037.

3. Cuffe, S. T. Development of Federal Standards of Performance. U.S. Environmental Protection Agency, Office of Air Programs, Research Triangle Park, North Carolina. (Paper presented at the EPA Stationary Source Combustion Symposium. Atlanta. September 1974.)

4. Environmental Reporter. Current Developments Section. Vol. 6(33): 1393, December 12, 1975.

5. Sedman, C. B. Considerations for Federal Air Regulations for Coal Gasification Plants. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. (Paper presented at the 80th National Meeting of the American Institute for Chemical Engineers. Boston. September 1975.)

APPENDIX E

BIBLIOGRAPHY

SECTION II. INTEGRATION OF ENVIRONMENTAL ASSESSMENT ACTIVITIES WITH ENERGY SYSTEM DEVELOPMENT

Potentially Hazardous Emissions from the Extraction and Processing of Coal and Oil. Battelle, Columbus Laboratories. Prepared for U.S. Environmental Protection Agency, Office of Research and Development, NERC-RTP, Industrial and Environmental Research Laboratory, Research Triangle Park, North Carolina. Publication Number EPA-650/2-75-038. April 1975.

Symposium Proceedings: Environmental Aspects of Fuel Conversion Technology. St. Louis, Missouri. May 1974. U.S. Environmental Protection Agency, Office of Research and Development. Publication Number EPA-650/2-74-118. October 1974.

Program Plan for Environmental Effects of Energy. Mitre Corporation. Sponsored by National Science Foundation. Publication Number PB-235 115. July 1974.

Energy Research Program of the U.S. Department of the Interior. Prepared by Office of Research and Development. U.S. Government Printing Office. Publication Number 0-537-710. March 1974.

Energy Alternatives and Their Related Environmental Impacts. Bureau of Land Management, U.S. Department of the Interior. December 1973.

Environmental Considerations in Future Environmental Growth. Battelle Columbus and Pacific Northwest Laboratories. Prepared for U.S. Environmental Protection Agency, Contract Number 68-01-0470. 1973.

Energy Resources and the Environment. Mitre Corporation, McLean, Virginia. Report Number PB 213031/8. October 1972.

An Evolutionary, Normaltive Methodology for Environmental Assessment. Mitre Corporation. Report Number MTR-4172. October 1970.

SECTION III. PROCESS CHARACTERIZATION AND WASTE STREAM ANALYSIS

Slaminski, J.M. Steam-Electric Unit Operating Parameters in Relation to the Emission of Particulate Matter, Sulfur Dioxide and Nitrogen Dioxides. AICHE Symposium Series. 70(137):510. 1974.

USEPA Effluent Guidelines Division, Office of Water and Hazardous Substances: Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Steam Electric Power Generating Point Source Category. U.S. Environmental Protection Agency, Office of Research and Development. Publication Number EPA-440/1-74-029a Group 1. October 1974.

Study of Potential Problems and Optimum Opportunities in Retrofitting Industrial Processes to Low and Intermediate Energy Gas From Coal. U.S. Environmental Protection Agency, Office of Research and Development. Publication Number 650/2-74-052. May 1974.

Danielson, John A. Air Pollution Engineering Manual (Second Edition). Los Angeles County, Air Pollution Control District, and U.S. Environmental Protection Agency, Office of Air and Water Programs. Publication Number AP-40. May 1973.

SECTION IV. ESTIMATE POLLUTION FROM ASSOCIATED DEVELOPMENT

General Environmental Issues and Analyses

Reitze, Arnold W., Jr. Environmental Law. Second Edition. North American International. Washington, D.C. 1972.

Reitze, Arnold W. Environmental Planning: Law of Land and Resources. North American International. Washington, D.C. 1974.

Council on Environmental Quality. Environmental Quality - Annual Reports. 1970-1975.

Yarrington, Hugh J. The National Environmental Policy Act. Environment Reporter. Monograph Number 17, The Bureau of National Affairs, Inc. 4(36), January 4, 1974.

The Costs of Sprawl. Environmental and Economic Costs of Alternative Residential Development Patterns at the Urban Fringe. Vol. 1: Detailed Cost Analysis. Vol. 2: Literature Review and Bibliography. Prepared for the Council on Environmental Quality, The Office of Policy Development and Research, Department of Housing and Urban Development and the Office of Planning and Management, U.S. Environmental Protection Agency, by Real Estate Research Corporation. April 1974.

Environmental Quality Guidelines

U.S. Environmental Protection Agency. Preparation of Environmental Impact Statements: Final Regulations. Federal Register. Vol. 40, Number 72. April 14, 1975. p. 16813-16827.

Leopold, Luna B. et al. A Procedure for Evaluating Environmental Impact. U.S. Geological Survey. Circular 645. Government Printing Office, Washington, D.C. 1971.

Land Resources and Environmental Impacts

Haskell, Elizabeth H. Land Use and the Environment: Public Policy Issues. Environment Reporter. Monograph Number 20, The Bureau of National Affairs, Inc. 5(28), November 8, 1974.

Water Resources and Environmental Impacts

Hittman Associates, Inc. Forecasting Municipal Water Requirements. Columbia, Maryland. National Technical Information Service. 1969. p. 1901275.

Porges, Ralph. Factors Influencing per Capita Water Consumption. Water and Sewage Works. Vol. 104. May 1957.

Linneauer, F.P., Jr., John C. Geyer, and Jerome B. Wolfe. A Study of Residential Water Use. Study prepared for the Federal Housing Administration. Washington, D.C. Government Printing Office. 1967.

Sayers, William T. Water Quality Surveillance. The Federal-State Network. Environmental Science and Technology. February 1971.

The Impact of Energy Development on Water Resources in Arid Lands: Literature Review and Annotated Bibliography. Arizona University. Prepared for Office of Water Research and Technology. January 1975.

Berlin, Harriet G. Federal Aids for Water Pollution Control. Environment Reporter. Monograph Number 1, Bureau of National Affairs, Inc. 1(1), May 1, 1970.

Clark, Viessman, and Hammer. Water Supply and Pollution Control. International Textbook Company. Scranton, Pennsylvania. 1971.

Rahn, P.H. Movement of Dissolved Salts in Ground Water Systems. Symposium on Pollutants in the Roadside Environment. University of Connecticut and Connecticut State Highway Department. 29 February 1969. p. 36-45.

Pitt, R.E., and G. Amy. Toxic Materials Analysis of Street Surface Contaminants. U.S. Environmental Protection Agency, Raleigh, North Carolina. Publication Number EPA-R2-73-283. August 1973.

Sartor, J.D. and G.B. Boyd. Water Pollution Aspects of Street Contaminants. U.S. Environmental Protection Agency, Raleigh, North Carolina. Publication Number EPA-R2-72-081. November 1972.

Cost of Clean Water, Volume II. Cost Effectiveness and Clean Water. U.S. Environmental Protection Agency, Water Quality Office, Raleigh, North Carolina. March 1971.

Air Impacts

Ott, W., J. F. Clarke, and G. Ozolins. Calculating Future Carbon Monoxide Emissions and Concentrations from Urban Traffic Data. U.S. Public Health Service. Publication Number 999-AP-41. Cincinnati. 1967.

Guidelines for Air Quality Maintenance Planning and Analysis:
Volume 1: Designation of Air Quality Maintenance Areas
Volume 2: Plan Preparation
Volume 3: Control Strategies
Volume 4: Land Use and Transportation Consideration
Volume 5: Case Studies in Plan Development
Volume 6: Overview of Air Quality Maintenance Area Analysis
Volume 7: Projecting County Emissions
Volume 8: Computer-Assisted Area Source Emissions Gridding Procedure
Volume 9: Evaluating Indirect Sources
Volume 10: Reviewing New Stationary Sources
Volume 11: Air Quality Monitoring and Data Analysis
Volume 12: Applying Atmospheric Simulation Models to Air Quality Maintenance Areas
Volume 13: Allocating Projected Emissions to Sub-County Areas
U.S. Environmental Protection Agency, Office of Air and Waste Management. Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina. 1974-1975.

Roberts, John J., Edward J. Croke, and Samuel Booras. A Critical Review of the Effect of Air Pollution Control Regulations on Land Use Planning. J Air Pollut Control Assoc. 25(5), May 1975.

Neustadter, E.C., S.M. Sidik, and J.C. Burr, Jr. Statistical Summary and Trend Evaluation of Air Quality Data for Cleveland, Ohio, in 1967 and 1971; Total Suspended Particulate, Nitrogen Dioxide, and Sulfur Dioxide. NASA TN D-6935. September 1972.

Stolzenbach, K.D. and D.R.F. Harleman. Analytical and Experimental Investigation of Surface Discharges of Heated Water. U.S. Environmental Protection Agency, Raleigh, North Carolina. Publication Number 16130 DJU02/71. February 1971.

Cermak, J.E. Air Motion in and Near Cities - Determination by Laboratory Simulation. Colorado State University Fluid Mechanics Program Technical Paper. Publication Number CEP 70-71JEC27. 1971.

Koh, R.C.Y., and L. Fan. Mathematical Models for the Prediction of Temperature Distributions Resulting from the Discharge of Heated Water into Large Bodies of Water. U.S. Environmental Protection Agency, Raleigh, North Carolina. Publication Number 16130 DWO 10/70. October 1970.

Noise Impacts

Greenwald, Alan G. Law of Noise Pollution. Environment Reporter. Monograph Number 2, Bureau of National Affairs, Inc. 1(1), May 1, 1970.

Senku, Alexander et al. Urban Noise Survey Methodology. L.S. Goodfriend and Associates. Prepared for New York City (NYC) Department of Air Resources, Bureau of Noise Abatement. N.Y.C., N.Y. and U.S. Department of Housing and Urban Development, Washington, D.C. National Technical Information Service. November 1971. p. 211631.

Other Environmental Impacts

Weston, Roy, F., Inc. Macon County Solid Waste Management System Analysis. Project Number 40.00 for State of Illinois, Chicago, Illinois. Institute for Environmental Quality. April 1974.

Tassett, Ann. Solid Waste Programs and Research. Environmental Reporter. Monograph Number 6, The Bureau of National Affairs, Inc. 1(1), December 11, 1970.

SECTION V. ESTIMATING THE SPHERE OF ENVIRONMENTAL INFLUENCE

Monitoring and Air Quality Trends Report. Monitoring and Data Analysis Division, U.S. Environmental Protection Agency, Raleigh, North Carolina. Publication Number EPA-450/1-74-007. October 1974.

Karubian, J.F. Polluted Groundwater: Estimating the Effects of Man's Activities. U.S. Environmental Protection Agency, Las Vegas, Nevada. Publication Number EPA-680/4-74-002. July 1974.

SECTION VI. ASSESSING THE ENVIRONMENTAL IMPACTS OF ENERGY SYSTEMS

Theis, T.L. The Potential Trace Metal Contamination of Water Resources Through the Disposal of Fly Ash. Paper presented at 2nd National Conference on Complete Water Reuse. Chicago, Illinois. May 1975.

Sather, N.F. and W.M. Swift. Potential Trace Element Emissions From the Gasification of Illinois Coals. Argonne National Laboratory. March 1975.

Axtmann, R.C. Environmental Impact of A Geothermal Power Plant. Science. 187:4179. 1975.

The Impact of Energy Development on Water Resources in Arid Lands: Literature Review and Annotated Bibliography. Arozona University. Publication Number PB-240-008. January 1975.

Degradation Mechanisms: Controlling the Bioaccumulation of Hazardous Materials. National Environmental Research Center, Office of Research and Development, U.S. Environmental Protection Agency. Cincinnati, Ohio. Publication Number EPA-670/2-75-005. January 1975.

Report of the Interagency Working Group on Health and Environmental Effects of Energy Use. Interagency Working Group on Health and Environmental Effects of Energy Use. Council on Environmental Quality. November 1974.

The Bioenvironmental Impact of Air Pollution From Fossil-Fuel Power Plants. National Environmental Research Center, Office of Research and Development, U.S. Environmental Protection Agency, Corvallis, Oregon. Publication Number EPA-660/3-74-011. August 1974.

Solid Waste Disposal. Radian Corporation. Prepared for U.S. Environmental Protection Agency. Publication Number EPA-650/2-74-033. May 1974.

Development of Predictions of Future Pollution Problems. Prepared by Implementation Research Division, Washington Environmental Research Center. U.S. Environmental Protection Agency. Publication Number EPA-600/2-74-002. March 1974.

Energy Production and Thermal Effects. Limnetics, Inc. Proceedings of a Symposium held at the Oak Brook Hyatt House, Oak Brook, Illinois. September 10-11, 1973.

Public Health and Welfare Criteria for Noise. U.S. Environmental Protection Agency, Office of Noise Abatement and Control. Publication Number EPA-550/9-73-002. July 27, 1973.

Calvert, J.G. Interactions of Air Pollutants. Proceedings of the Conference on Health Effects of Air Pollution, National Academy of Sciences. October 3-5, 1973. Serial Number 93-15. p. 709.

The Environmental Flow of Cadmium and Other Trace Metals. Volume I. Progress Report July 1, 1972, to June 30, 1973. Purdue University. NISF (RANN) Grant GI-35106. Publication Number PB 829478.

Beryllium and Air Pollution: An Annotated Bibliography. U.S. Environmental Protection Agency, Air Pollution Control Office. Publication Number AP-83. February 1971.

Pollutant Impact on Horticulture and Man. Hort Sci. 5:244, 1970.

Kemp et al. Water Quality Criteria Data Book: Effects of Chemicals on Aquatic Life, Vol. 3. Battelle Columbus Laboratories. U.S. Environmental Protection Agency. Publication Number EPA 18050 GWV 05/71. May 1971. (Literature through 1968.)

Kemp, H.J., R.L. Little, V.L. Holoman, and R.L. Darby. Water Quality Criteria Data Book: Effects of Chemicals on Aquatic Life, Vol. 5. Battelle Columbus Laboratories. U.S. Environmental Protection Agency. Publication Number EPA 18050 HLA 09/73. September 1973. (Literature 1968-1972.)

APPENDIX A. SOURCE AND AMBIENT TESTING AS PART OF AN ENVIRONMENTAL ASSESSMENT PROGRAM

Air

Sulfur Compounds -

Natusch, D.F.S., J.R. Sewell, and R.L. Tanner. Determination of Hydrogen Sulfide in Air - An Assessment of Impregnated Paper Tape Methods. Anal Chem. 46:410-415, March 1974.

Collaborative Study of Method for the Determination of Sulfur Dioxide Emissions From Stationary Sources (Fossil-Fuel-Fired Steam Generators). Southwest Research Institute. Prepared for U.S. Environmental Protection Agency. Publication Number EPA-650/4-74-024. December 1973.

Monitoring Instrumentation for the Measurement of Sulfur Dioxide in Stationary Source Emissions. TRW Systems Group. 1973.

Forrest, J., and L. Newman. Ambient Air Monitoring for Sulfur Compounds. J Air Pollut Control Assoc. 23:761-768, September 1973.

Nitrogen Compounds -

Bruening, M.L., and L.H. Wullstein. Controlled Atmosphere Technique for Measurement of Molecular Nitrogen, Nitric Oxide, Nitrous Oxide, and Oxygen by Gas Chromatography. Environ Sci Technol. 8:72-75, January 1975.

Collaborative Test of the TGS-ANSA Method for Measurement of Nitrogen Dioxide in Ambient Air. Midwest Research Institute. Prepared for U.S. Environmental Protection Agency. Publication Number EPA-650/4-74-046. September 1974.

Evaluation of Triethanolamine Procedure for Determination of Nitrogen Dioxide in Ambient Air. Quality Assurance and Environmental Monitoring Laboratory. Prepared for U.S. Environmental Protection Agency. Publication Number EPA-650/4-74-031. July 1974.

Collaborative Study of Method for the Determination of Nitrogen Oxide Emissions from Stationary Sources (Fossil-Fuel-Fired Steam Generators). Southwest Research Institute. Prepared for U.S. Environmental Protection Agency. Publication Number EPA-650/4-74-025. October 1973.

Hydrocarbons -

Altshuller, A.P., W.A. Lonneman, and S.L.Kopczynski. NonMethane Hydrocarbon Air Quality Measurement. J Air Pollut Control Assoc. 23:597-599, July 1973.

Giger, W., and M. Blumer. Polycyclic Aromatic Hydrocarbons by Chromatography, Visible, Ultraviolet, and Mass Spectrometry. Anal Chem. 46:1663-1671, October 1974.

Feldstein, M. Regulations for the Control of Hydrocarbon Emissions From Stationary Sources. J Air Pollut Control Assoc. 24:469-478, May 1974.

Mieure, J.P., and M.W. Dietrich. Determination of Trace Organics in Air and Water. J Chromatographic Sci. Vol. 11, November 1973. p. 559-570.

Trace Elements -

Electron Spectroscopy Analysis of the Atomic Content of Samples of Occupational Health Interest. National Institute for Occupational Safety and Health. Publication Number NIOSH-75-130. January 1975.

Sugimae, A. Emission Spectrographic Determination of Trace Elements in Airborne Particulate Matter. Anal Chem. 46:1123-1125, July 1974.

Lee, R.E., Jr. and D.J. von Lehmden. Trace Metal Pollution in the Environment. J Air Pollut Control Assoc. 23:853-857, October 1973.

Survey of Manual Methods of Measurements of Asbestos, Beryllium, Lead, Cadmium, Selenium, and Mercury in Stationary Source Emissions. Stanford Research Institute. Prepared for U.S. Environmental Protection Agency, Environmental Monitoring Series, Office of Research and Development, Washington, D.C. Publication Number EPA-650/4-74-015. September 1973.

Particulate Matter -

Administrative and Technical Aspects of Source Sampling for Particulates. PEDCo Environmental Specialists, Inc. Prepared for U.S. Environmental Protection Agency. Publication Number EPA-450/3-74-047. August 1974.

Duvall, P.M. and R.C. Bourke. Personal and High-Volume Air-Sampling Correlation Particulates. Environ Sci Technol. 8:765-767, August 1974.

Collaborative Study of Method for the Determination of Particulate Matter Emissions from Stationary Sources (Fossil-Fuel-Fired Steam Generators). Southwest Research Institute. Prepared for U.S. Environmental Protection Agency. Publication Number EPA-650/4-74-021. June 1974.

Other -

Saltzman, B.E., and J.E. Cuddeback. Air Pollution. Anal Chem. 47:1R-15R, April 1975.

U.S. Environmental Protection Agency. Ambient Air Monitoring Reference and Equivalent Methods. Fed Regis. Vol. 40, Number 31, Part II, February 18, 1975.

Guidelines for Development of a Quality Assurance Program. Volume III Determination of Moisture in Stack Gases. U.S. Environmental Protection Agency, Research Triangle Institute, North Carolina. Publication Number EPA-650/4-005c. August 1974.

Monitoring and Air Quality Trends Report. U.S. Environmental Protection Agency, Office of Air and Waste Management, Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina. Publication Number EPA-650/1-74-007. October 1974.

Designation of Unacceptable Analytical Methods of Measurement for Criteria Pollutants. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Publication Number EPA-450/4-74-005. September 1974.

Neustadter, H.E., and S.M. Sidik. On Evaluating Compliance With Air Pollution Levels Not To Be Exceeded More Than Once A Year. J Air Pollut Control Assoc. 24:559-563, June 1974.

Chapman, R.L. Continuous Stack Monitoring. Environ Sci Technol. 8:520-525, June 1974.

Report on Analytical Methods Used in a Coke Oven Effluent Study, The Five Oven Study. U.S. Department of HEW Public Health Service. Center for Disease Control. National Institute for Occupational Safety and Health. Division of Laboratories and Criteria Development. Cincinnati, Ohio. May 1974.

Schulte, K.A., D.J. Larsen, R.W. Harnung, and J.V. Crable. Report on Analytical Methods Used in Coke Oven Effluent Study. National Institute for Occupational Safety and Health, Cincinnati, Ohio. May 1974.

Smith, F., D.E. Wagoner, and A.C. Nelson, Jr. Guidelines for Development of a Quality Assurance Program: Vol. I: Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S-Pitot Tube). U.S. Environmental Protection Agency, Quality Assurance and Environmental Monitoring Laboratory, Research Triangle Park, North Carolina. Publication Number EPA-650/4-74-005b. February 1974.

Smith, F., D.E. Wagoner, and A.C. Nelson, Jr. Guidelines for Development of a Quality Assurance Program: Vol. II: Gas Analysis for Carbon Dioxide, Excess Air, and Dry Molecular Weight. U.S. Environmental Protection Agency, Quality Assurance and Environmental Monitoring Laboratory, Research Triangle Park, North Carolina. Publication Number EPA-650/4-74-005b. February 1974.

Nader, J.S., F. Jaye, and W. Couner. Performance Specifications for Stationary - Source Monitoring Systems for Gases and Visible Emissions. U.S. National Environmental Research Center, Research Triangle Park, North Carolina. Publication Number EPA-650/2-74-013. January 1974.

Progress in Instrumentation and Techniques for Measurement of Air Pollutants. U.S. Environmental Protection Agency, Office of Research and Development. Publication Number EPA-650/2-74-015. January 1974.

Schneider, T. Automatic Air Quality Monitoring Systems. New York, American Elsevier Publishing Company, Inc. 1974.

Development and Testing of an Air Monitoring System. Research Triangle Institute, Research Triangle Park, North Carolina. Prepared for Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C. Publication Number EPA-650/2-74-019. December 1973.

Survey of Various Approaches to the Chemical Analysis of Environmentally Important Materials. U.S. National Bureau of Standards. COM-74-10469, July 1973.

Nader, J.S. Developments in Sampling and Analysis Instrumentation for Stationary Sources. J Air Pollut Control Assoc. 23:587-591, July 1973.

Compendium of Analytical Methods - Volume I Matrix. Compendium of Analytical Methods - Volume II Method Summaries. Mitre Corporation. Publication Number EPA-R4-73-027a and EPA-R4-73-027b. 1973.

Guidelines: Air Quality Surveillance Networks. Office of Air Programs Publication Number AP-98 by Environmental Protection Agency, Office of Air Programs. May 1971.

Water

Organics -

Identification of Organic Compounds in Effluents from Industrial Sources. U.S. Environmental Protection Agency. Publication Number EPA-560/3-75-002. April 1975.

Harris, L.E., W.E. Budde, and J.W. Eichelberger. Direct Analysis of Water Sample for Organic Pollutants With Gas Chromatography. Mass Spectrom. 46:1912-1917, November 1974.

Brown, E., M.W. Skongstad, and M.J. Fishman. Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases. Book 5, Chapter A1 of Techniques of Water Resources Investigations of the U.S. Geological Survey. Government Printing Office Stock No. 2401-1015. 1974.

Goerli, D.F., and E. Brown. Methods for Analysis of Organic Substances in Water. Book 5, Chapter A3 of above. U.S. Geological Survey. 1972.

Slack, K.V., R.C. Averett, P.E. Greeson, and R.G. Lipscomb. Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples. Book 5, Chapter A4 of above. U.S. Geological Survey. 1973.

Ma, T.S., and M. Gutterson. Organic Elemental Analysis. Anal Chem. 46:437R-451R, April 1974.

Hites, R.A. Analysis of Trace Organic Compounds in New England Rivers. J Chromatographic Sci. 11:570-574, November 1973.

Current Practice in GC-MS Analysis of Organics in Water. Southeast Environmental Research Laboratory, sponsored by National Environmental Research Center, Office of Research and Monitoring. U.S. Environmental Protection Agency, Corvallis, Oregon. Publication Number EPA-R2-73. August 1973.

Minear, R.A. et al. Organics. J Water Pollut Control Fed. 45:982-986, June 1973.

Inorganics -

Chen, K.Y., C.S. Young, T.K. Jan, and N. Rohathi. Trace Metals In Wastewater Effluents. J Water Pollut Control Fed. 46:2663-2675, December 1974.

Coleman, R.F. Comparison of Analytical Techniques for Inorganic Pollutants. Anal Chem. 46:989A-996A, October 1974.

Mytelka, A.I., J.S. Czachor, W.B. Guggino, and H. Golub. Heavy Metals in Wastewater and Treatment Plant Effluents. J Water Pollut Control Fed. 45:1859-1864, September 1973.

Carlton, T.L., I.L. Smith, and J.V. Walters. Major Inorganics. J Water Pollut Control Fed. 45:979-982, June 1973.

Boyer, J.F., and V.E. Gleason. Coal and Coal Mine Drainage. J Water Pollut Control Fed. 45:1179-1184, June 1973.

Barnett, Paul R., and E.C. Mallory Jr. Determination of Minor Elements in Water by Emission Spectroscopy. Book 5, Chapter A2 of Techniques of Water Resources Investigations of the U.S. Geological Survey. 1971.

Other -

Fishman, M.J., and D.E. Erdmann. Water Analysis. Anal Chem. 47:334R-361R, April 1975.

Roesler, J.F., and R.H. Wise. Variables to be Measured in Wastewater Treatment Plant Monitoring and Control. J Water Pollut Control Fed. 46:1769-1775, July 1974.

Brezonik, P.L. Continuous Monitoring, Automated Analysis, and Sampling Procedures. J Water Pollut Control Fed. 46:1100-1109, June 1974.

Manual for Evaluating Public Drinking Water Supplies - A Manual of Practice. U.S. Environmental Protection Agency Office of Water and Hazardous Substances. 1974. (No number. Formerly known as PHS Pub. No. 1820.)

Manual of Methods for Chemical Analysis of Water and Wastes. National Environmental Research Center, Cincinnati, Ohio 45268. Publication Number EPA-625/6-74-003. 1974.

Biological Field and Laboratory Methods For Measuring the Quality of Surface Waters and Effluents. National Environmental Research Center, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio. Publication Number EPA-670/4-73-001. July 1973.

Herbes, S.E., and H.E. Allen. Continuous Monitoring, Automated Analysis, and Sampling Procedures. J Water Pollut Control Fed. 45:1018-1026, June 1973.

Ghosh, M.M. Water Characteristics. J Water Pollut Control Fed. 45:986-995, June 1973.

Young, R.H. F. Effects on Groundwater. J Water Pollut Control Fed. 45:1296-1301, June 1973.

Fishman, M.J., and D.E. Erdman. Water Analysis. Anal Chem. 45:361R-403R, April 1973.

Bender, D.F., M.L. Peterson, and H. Stierli (eds.). Physical, Chemical, and Microbiological Methods of Solid Waste Testing. U.S. Environmental Protection Agency, Cincinnati, Ohio. Publication Number EPA-6700-73-01. May 1973.

Handbook for Analytical Quality Control in Water and Wastewater Laboratories, Analytical Quality Control Laboratory. National Environmental Research Center, Cincinnati, Ohio. June 1972.

Miscellaneous

TRW, Procedures for Process Measurements Trace Inorganic Materials. Prepared for U.S. Environmental Protection Agency, Office of R&D, Triangle Park, North Carolina. Contract No. 68-02-1393. July 1975.

Chian, S.K., and F.B. DeWalle. Compilation of Methodology Used for Measuring Pollution Parameters of Sanitary Landfill Leachate. Department of Civil Engineering, University of Illinois. For the: National Environmental Research Center, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio. 1974.

Research Facilities Necessary to Adequately Support Measurement of Low Levels of Pollutants and Follow Their Trends. Organization for Economic Cooperation and Development, Environment Directorate. 1971.

APPENDIX B. DISPERSION MODELS

Comprehensive Analysis of Time Concentration Relationships and the Validation of a Single-Source Dispersion Model. Final Report. GCA/Technology Division, Prepared for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Contract No. 68-02-1376. March 1975.

Korshover, J. Synoptic Climatology of Stagnating Anticyclones East of the Rocky Mountains in the United States for the Period 1936-1956. US HEW - PHS SEC-TR-A60-7, 1960.

Shirazi, M.A., and L.R. Davis. Workbook of Thermal Plume Prediction. Vol. 2, Surface Discharge. U.S. Environmental Protection Agency. Publication Number EPA-R2-72-005b. May 1974.

Holzworth, G.C. Meteorological Episodes of Slowest Dilution in the Contiguous United States. U.S. Environmental Protection Agency. Publication Number EPA-650/4-74-002. February 1974.

National Air Monitoring Program: Air Quality and Emissions Trends. Annual Report Volume 1. U.S. Environmental Protection Agency Monitoring and Data Analysis Division. Publication Number EPA-450/1-73-001a. August 1973.

Solid Waste Management Information Materials. U.S. Environmental Protection Agency. Report Number SW-58 19. July 1973.

Montgomery, T.L., W.B. Norris, F.W. Thomas, and S.B. Carpenter. A Simplified Technique Used to Evaluate Atmospheric Dispersion of Emissions From Large Power Plants. J Air Pollut Control Assoc. 23:388-394. May 1973.

Trent, D.S., and J.R. Welty. Numerical Thermal Plume Model for Vertical Outfalls into Shallow Water. U.S. Environmental Protection Agency. Publication Number EPA-R2-73-162. March 1973.

APPENDIX C. DATA RETRIEVAL AND INFORMATION SYSTEMS APPLICABLE TO ENVIRONMENTAL ASSESSMENTS

ORD Publications Summary. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. Publication Number EPA-600/9-75-001a. March 1975.

Indexed Bibliography of Office of Research and Development Reports. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. Publication Number EPA-600/9-74-001. July 1974.

Energy Research and Technology. Interim Bibliography of Reports with Abstracts. Rann Document Center. Ref. NSF 74-22. June 1974.

Where to Find State Plans to Clean the Air. U.S. Environmental Protection Agency, Washington, D.C. April 1974.

The Energy Index: A Select Guide to Energy Information Since 1970. Environmental Information Center. 1973.

A Supplemental Bibliography of Publications on Energy. U.S. Senate, Committee on Interior and Insular Affairs. 1972.

APPENDIX D. POLLUTANT LEGISLATION AND FUTURE PERSPECTIVES

Air Quality Criteria for Nitrogen Oxides. U.S. Environmental Protection Agency, Air Pollution Control Office. Publication Number AP-84. 1971.

Air Quality Criteria for Hydrocarbons. National Air Pollution Control Administration, Environmental Protection Agency. Publication Number AP-64. 1970.

McCune, D.C. The Technical Significance of Air Quality Standards: Fluoride Criteria for Vegetation Reflect the Diversity of Plant Kingdom. Environ Sci Technol. 3:720-727, 1969.

Air Quality Criteria for Sulfur Oxides. National Air Pollution Control Administration. Publication Number AP-50. 1969.

Air Quality Criteria for Particulate Matter. National Air Pollution Control Administration. Publication Number AP-49. 1969.

Federal Energy Administration, Energy Supply and Environmental Coordination Act of 1974, Section 2. Coal Conversion Program FES 45-1, Final Environmental Statement. April 1975.

Interim Primary Drinking Water Standards. U.S. Environmental Protection Agency. Fed Regis. 40:(51):Part II. March 14, 1975.

Thermal Discharges. U.S. Environmental Protection Agency. Fed Regis. 39(196):Part II, October 8, 1974.

Environmental Impact Requirements in the States: NEPA's Offspring. U.S. Environmental Protection Agency, Office of Research and Development. Publication Number EPA-600/5-74-006. April 1974.

Government Responsibilities for the Application and Control of Technology in Relation to Man's Environment. Organization for Economic Cooperation and Development, Environmental Directorate. 1971.